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A

MANUAL OF CHEMISTRY,

ON THE

BASIS OF PROFESSOR BRANDE'S;

CONTAINING

THE PRINCIPAL FACTS OF THE SCIENCE, ARRANGED IN THE ORDER IN WHICH THEY ARE DISCUSSED AND ILLUSTRATED IN THE LECTURES AT HARVARD UNIVERSITY, N. E.

COMPILED FROM THE WORKS OF

BRANDE, HENRY, BERZELIUS, THOMSON AND OTHERS.

DESIGNED

AS A TEXT BOOK FOR THE USE OF STUDENTS, AND PERSONS ATTENDING LECTURES ON CHEMISTRY.

NEW YORK
PUB

BY

JOHN W. WEBSTER, M. D.

Lecturer on Chemistry in Harvard University.

BOSTON:
PUBLISHED BY RICHARDSON AND LORD.

J. H. A. Frost, Printer.
1826.

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TO

JOHN GORHAM, M. D.

ERVING PROFESSOR OF CHEMISTRY,

AND

JAMES JACKSON, M. D.

EY PROFESSOR OF THE THEORY AND PRACTICE OF PHYSICK,

IN HARVARD UNIVERSITY,

THE

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THE COMPILER.

presenting them in connection with any new experiments which intelligence might be received while the sheets w passing through the press.

Mr Brande's *Pharmacy* not having been received till th work was nearly ready for publication, the compiler was ab to avail himself of but a few of the statements contained in th valuable treatise.

To the gentlemen who have aided the compiler by their a vice and assistance, especially Professors Silliman and Cleav land, and Samuel Moore, Esq. Director of the United Stat Mint, he begs leave thus publicly to express his obligations.

Cambridge, June, 1826.

NOTE.

The letter	refers to
D	Davy's *Elements of Chemical Philosophy.*
H	" Henry's " *Chemistry.*
U	" Ure's *Dictionary of Chemistry.*
M	" Murray's *System of* do.
T	" Thomson's do. do. and *Attempt to establish th first Principles of Chemistry by Experiment.*

TO

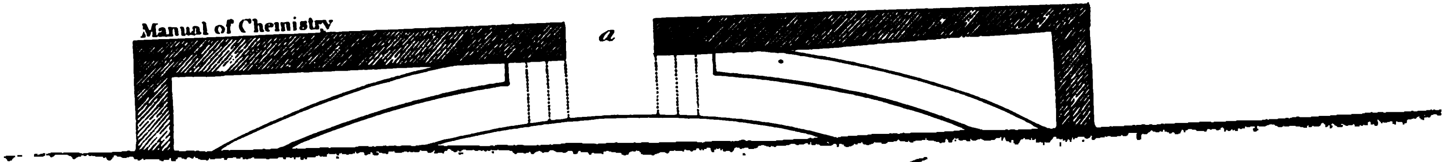
JOHN GORHAM, M. D.

ERVING PROFESSOR OF CHEMISTRY,

Geo. O. Foster,
Cambridge.

THE COMPILER.

PL. VIII.



Plan of the Laboratory in Harvard College.

EXPLANATION OF PLATES VIII. AND IX.

ite VIII *is a ground plan of the Chemical Laboratory Lecture Room in Harvard College.*

a part appropriated to the audience, *a* entrance.

the body of the laboratory. *b* lecture table containing *c c* cisterns for urnished with stop-cocks projecting through the covers, which can be ed when large jars are to be filled. To the stop-cocks flexible tubes e connected to form the oxy-hydrogen blow-pipe, the tubes communi- with a jet formed of two cones, see section (fig. 16, pl. 9.) *d*, pneu- table, (fig. 73, pl. 3.) *e*, furnace stove. *f*, mercurial cistern, (pl. 3, .) *g*, Table with electrical machine. *h*, Table with air pump. *i i i i*, for apparatus. *k*, Large Calorimotor. *l*, Deflagrator. *m*, Small uni- furnace.

Table with drawers in the form of a double cross, for the general uses of boratory.

Table with vice, anvils, mortars, files, &c.

Table with balances in glazed cases.

maller table.

Sink, pump, bottle racks, &c.

and bath. 2, a furnace for the production of oxygen and other gases. nd furnace with air flues (13) under the floor of the laboratory. See Sec- l. 9, fig. 2). 4, Assay furnace. 5, Forge. 6, A copper boiler, (plate 97,) &c. 7, Refrigeratory. 8, Anvil. 9, Universal furnace, (fig. 3, pl. 0, Copper gasometer, from which tubes pass into the lecture room. 11, lders. 12, Racks, with test tubes, &c. (see figs. 17 and 18, pl. 9.) 14, Mortar. 15, Door communicating with the lecture room.

te IX *exhibits sections of the furnaces, and views of il useful parts of the apparatus not described in the of the work.*

l is a section of the sand furnace, 1 Pl. 8.

! is a ditto of the wind ditto, 3 Pl. 8. *a* is a flue communicating with erior of the building for the admission of cold air to the fire place. *b* -pit. *c* a plate of iron to direct the current of air through the grate *d*. eable cover. *f* the chimney.

ight's improved Black's portable furnace. *a* iron kettle to contain hich fits into the opening at the top of the furnace. *b* a cover. *c* e to which there is a corresponding one on the opposite side for the ion of a tube to pass through the furnace.

cupelling or enamelling furnace. *a* the ash-pit. *c* the grate. *d* the *e* the opening for introducing the muffle. *f* the chimney. *g* the

portable furnace of earthen ware which may be placed on a table. e furnaces are manufactured by Mr Miller, of Philadelphia, and are con- ent for many purposes.

6 A filtering bag. 7, 8 and 9 Evaporating basins.

10 A platinum crucible and cover. 11 Skittle shaped crucible. 12 Covered do. 13 An iron ring covered with cloth for supporting retorts.

14 A small Calorimotor for exploding gases by the ignition of a fine platinum wire, in the glass vessel fig. 15. The vessel having been filled with the mixed gases, by means of the air pump, is placed upon the cross bar of the Calorimotor and the thick wires *a a*, which are connected by the *fine* platinum wire *b*, are brought in contact with the poles of the calorimotor by means of the screws *a a*, fig. 14. A copper vessel, coated within and without with cement, is represented beneath the plates of the instrument. The contact being made, the copper vessel containing the liquor is raised until the plates are immersed, when the small wire *b* is instantly ignited. For a full account of this most convenient apparatus see Dr Hare's description in the American Journal of Science, vol. x. 67.

16 Jet for the oxy-hydrogen blow-pipe, formed of two cones, with an intervening space. *a* an internal screw communicating with the space *between* the cones; *b* a similar screw communicating only with the *inner* cone. The gases issue at the orifices *c*, and either gas may be made to surround the other.

17 A filtering stand.

18 A rack for test-glasses.

19 A small anvil.

20 Alcohol blow-pipe, *a* a spherical copper vessel furnished with a safety valve *b*; the alcohol being made to boil by the flame of the lamp *c*, its vapour passes out through the jet *d*, just above the wick of the lamp, which inflames it.

21 is the muffle represented at *d*, fig. 4.

22 Precipitating jars.

23 Hessian crucibles.

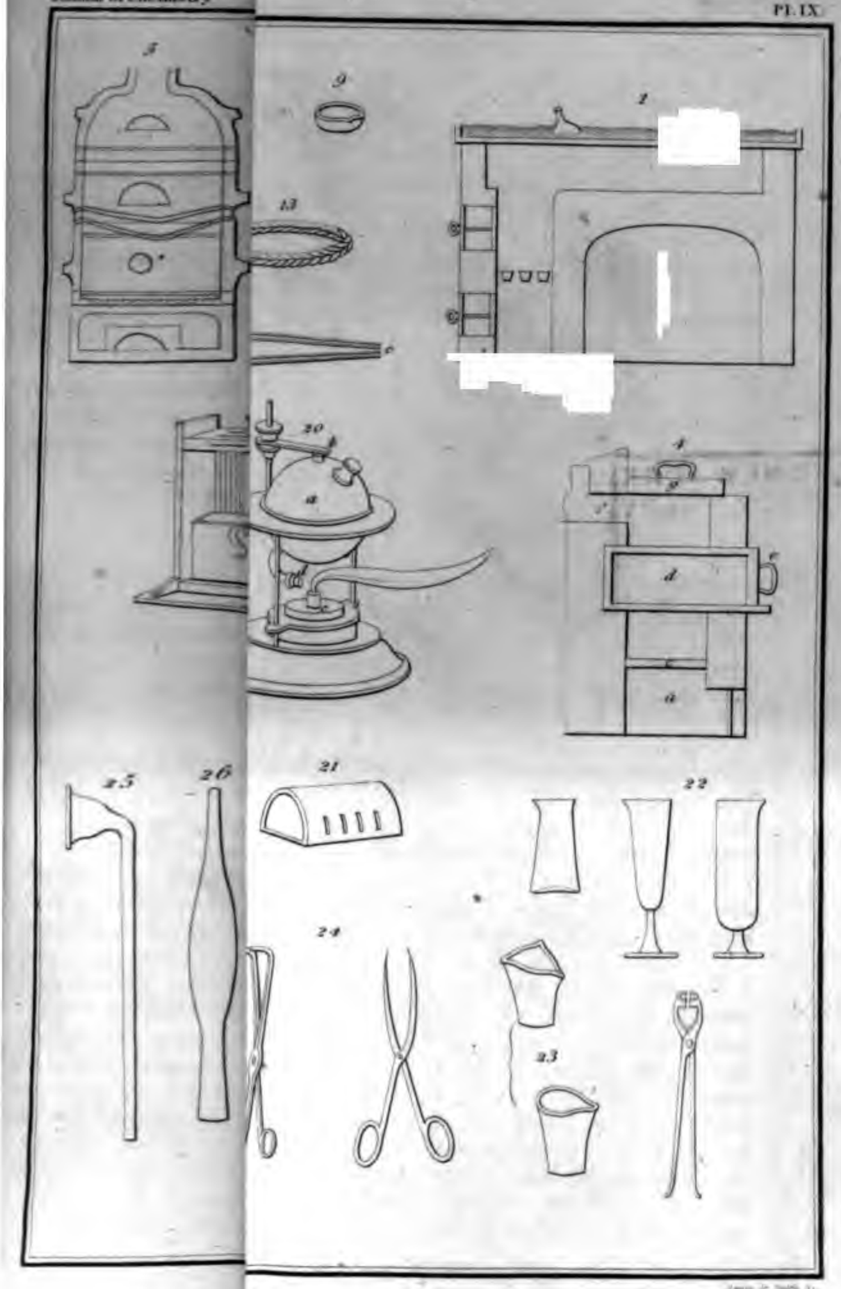
24 The principal varieties of tongs useful in the laboratory.

25 A long funnel for introducing liquids into retorts without soiling their necks.

26 An adopter for lengthening the necks of retorts.

Fig. 27, is a vertical section of one of the cisterns within the lecture table (*c c* of plate viii.) One half of each is covered so as to form an air-tight box, the partition, which divides the cistern and forms one side of the box, descending to within two inches of the bottom. *d*, *e* are two air-cocks, one vertical, the other horizontal. The air cocks being open the cistern is filled with water, they are then closed, and the cock at *f* opened which allows the water to escape till the lower edge of the partition is nearly uncovered; the water remaining within the box *a*. A tube *c* passes down the side of the cistern and along its bottom, turning up under the partition; through this any gas may be introduced, which, rising, displaces the water in *a*, causing it to pass into the other part of the cistern *b*. When the gas is wanted for use it is only necessary to open one of the air-cocks *e*, *d*, and the water in *b* falling expels the gas from *a* through it, where it may be received in air jars placed over the horizontal cock, or be allowed to pass into a tube screwed upon *d*.

Manual of Chemistry. Pl. IX.



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ERRATA.

Page 9, line 13, for sulphate, read sulphuret.
11, " 10, " " fig. 48" read "53."
20, " 29, " 1824, " 1814.
23, " 25, " *b*, " *l*.
28, " 16, insert the sign — before 40°.
29, " 12, for "effected" read "affected."
35, " 15, " "directly" read "inversely."
46, for Pl 1, read Pl. 2.
67, 9th line from bottom, insert after "was" "connected, while the substance itself was."
68, 22d line, for "fig. 57" read "56."
77. 12 " insert "*a*" after "67."
77, 25 " after "*ff*" insert "and 82."
79, 24 " for "*c*" read "1."
88, in the second process for obtaining chlorine, insert after "retort" "and pour on them four ounces of sulphuric acid, which has been diluted previously with 4 ozs. of water and suffered to cool after dilution."
93, for "Chevenix" read "Chenevix."
104, for Pl. 2, read Pl. 4.
104, 11th line from the bottom read "88 and 77, *c*."
104, 7th " " dele "See fig. 85."
105, line 9, dele "fig. 97."
110, 7th line from the bottom insert after "97" "*a*."
178, first line of note for fig. 110, read fig. 112.
179, 3d line, for fig. 111, read fig. 113.
181, for fig. 112, read 114.
181, " 113, " 115.
182, " 114, " 116.
454, for chap. vi. read vii.
561, in margin, for "calculuus," read "calculus."

A
MANUAL OF CHEMISTRY.

CHAPTER I.

OF THE POWERS AND PROPERTIES OF MATTER, AND OF THE GENERAL LAWS OF CHEMICAL CHANGES.

Object of Chemistry.

1. It is the object of Chemistry to investigate all changes in the constitution of matter, whether effected by heat, mixture, or other means.[*]

Most of the substances belonging to our globe are constantly undergoing alterations in sensible qualities, and one variety of matter becomes as it were transmuted into another. Such changes, whether natural or artificial, whether slowly or rapidly performed, are called chemical; thus the gradual and almost imperceptible decay of the leaves and branches of a fallen tree exposed to the atmosphere, and the rapid combustion of wood in our fires, are both chemical operations. The object of chemical philosophy is to ascertain the causes of all phenomena of this kind, and to discover the laws by which they are governed.[†] The ends of this branch of knowledge are the application of natural substances to new uses, for increasing th comforts and enjoyments of man, and the demonstration of th order, harmony, and intelligent design of the system of th earth. D. l. i.

---

[*] The word *Chemistry* seems to be of Egyptian origin, and to have been originally equivalent to our phrase *natural philosophy* in its most extensive sense. In process of time it seems to have acquired a more limited signification, and to have been confined to *the art of working metals*. In the third century, we find it used in a much more limited sense, signifying the *art of making gold and silver*. Those who professed this art gradually assumed the form of a sect, under the name of Alchemists; a term which is supposed to be merely the word *chemist*, with the Arabian article *al* prefixed. The great object of the alchemists was to find out the means of converting the baser metals to gold, and the grand instrument by which this was to be effected was the philosopher's stone. T. i. 19.

[†] Chemistry is the science which treats of those events and changes in natural bodies, which are not accompanied by sensible motions. T. i. 18.

It is the object of Chemistry, to discover and explain the changes of composition that occur among the integrant and constituent parts of different bodies. H. i. 12.

Chemistry investigates those actions which are exerted between the minute particles of matter, at distances altogether imperceptible, causing them to pass into new arrangements and combinations, whence the properties of the bodies acted on are changed, their constitution is subverted, and new substances are formed. In conformity to these views the science may be defined, as that which investigates the combinations of matter and the agencies of those general powers whence these combinations are established and subverted. M. i. 1, 4.

2. The general range of Chemistry, is so extensive, and th individual cases requiring explanation, are so numerous, tha *arrangement* is of the first consequence to its successful study and in the present state of our knowledge, it will be foun most convenient to begin with the discussions relating to th general powers or properties of matter, and afterwards t proceed to the examination of individual substances, and to th phenomena which they offer when presented to each othe under circumstances favourable to the exertion of their mutu chemical agencies.

3. The powers and properties of matter, connected with che mical changes, may be considered under the heads of

1. Attraction.
2. Heat.
3. Electricity.

Foundations of chemical philosophy.

The foundations of chemical philosophy are observation, e periment, and analogy. By observation, facts are distinctl and minutely impressed on the mind. By analogy, similar fac are connected. By experiment, new facts are discovered; an in the progression of knowledge, observation, guided by ana ogy leads to experiment, and analogy confirmed by experimen becomes scientific truth. D. 1, 2.[*]

SECTION I. *Attraction.*

Attraction at sensible distances.

4. ALL bodies composing the material system of the un verse have a mutual tendency to approach each other, whats ever may be the distances at which they are placed. The op ration of this force extends to the remotest parts of the pla etary system, and is one of the causes that preserve t regularity of their orbits. The smaller bodies, also, that a under our more immediate observation, are influenced by t

---

[*] To give an instance.—Whoever will consider the slender green vegetable filaments (*confer rivularis*) which in summer exist in almost all streams, lakes, or pools, under the different circ stances of shade and sunshine, will discover globules of air upon the filaments exposed under wa to the sun but no air on the filaments that are shaded. He will find that the effect is owing to presence of light. This is an *observation;* but it gives no information respecting the nature of air. Let a wine glass filled with water be inverted over the confervæ, the air will collect in upper part of the glass, and when the glass is filled with air, it may be closed by the hand; place its usual position, and an inflamed taper introduced into it, the taper will burn with more brillia than in the atmosphere. This is an *experiment.* If the phenomena are reasoned upon and the qu tion is put, whether all vegetables of this kind, in fresh or in salt water, do not produce such air un like circumstances, the inquirer is guided by *analogy;* and when this is determined to be the case new trials, *a general scientific truth* is established; that all confervæ in the sunshine produ species of air that supports flame in a superior degree; which has been shown to be the case various minute investigations. D. 1. 2, 3.

same power, and fall to the earth's surface, when not prevented by the interference of other forces. From these facts the existence of a property has been inferred, which has been called *attraction*, or more specifically, the *attraction of gravitation.* Its nature is entirely unknown to us. H. 1, 28. The attraction between these bodies takes place at sensible distances; it exists in all known forms of matter; and it acts upon them directly as the mass, and inversely as the square of the distance.

Particles of bodies.

5. From reviewing bodies in the aggregate, we may next proceed to contemplate them as composed of minute particles. Of the nature of these particles we have no satisfactory evidence. In simple bodies the particles must be all of the same nature, or *homogeneous.* In compound bodies, we are to understand by the term *particles*, the smallest parts into which bodies can be resolved without decomposition. The word *atom* has of late been revived, to denote both these kinds of particles; and we may therefore, speak with propriety of *simple atoms* and of *compound atoms.* When two atoms of different kinds unite to form a third or compound atom, we may term the two first *component* atoms; and if these have not been decomposed, they may be called *elementary* or *primary atoms.* H. 1, 28.

Atoms.

Contiguous attraction.

6. Attraction is exerted between these minute particles, or atoms, when they are placed in apparent contact, and is effective only at insensible distances. This has been called *contiguous attraction*, and has been distinguished as it is exerted between particles of matter of the *same* kind, or between particles of a *different* kind. When the particles of the same kind are united to form an aggregate or mass, they are sometimes said to be united by the *affinity of aggregation, the cohesive affinity*, or by that force or power termed *cohesion.*

Cohesion.

Attraction at insensible distances.

7. The attraction which is exerted at insensible distances, preserves the form, and modifies the texture of solids, gives a spherical figure to fluids, causes the adhesion of surfaces, and influences the mechanical characters of bodies. When it operates upon *dissimilar* particles, it produces their union, giving rise to new and infinitely varied productions. It is this kind of attraction which is distinguished as *heterogeneous;* it is also called Chemical attraction, or Affinity.

8. The results of attraction, as relating to the texture and forms of matter, are influenced by the circumstances under which it has taken place. Sometimes the particles are, as it were indiscriminately collected; and at others they are beautifully arranged, giving rise to regular and determinate figures: in this case, bodies of the same composition almost invariably affect the same form; hence we are often enabled to infer the composition of a substance from accurate inspection of its external or mechanical characters.

Crystals.

9. The regular polyedral solids thus resulting from the influence of attraction upon certain kinds of matter, are usually

called *crystals;*[*] and the bodies are said to be susceptible of *crystallization.*

Conditions for crystallization.

10. To enable the particles of bodies to assume that regular form which crystals exhibit, it is obvious that they must have freedom of motion; and accordingly the first step towards obtaining a body in its crystalline form, is to confer upon it either the liquid or aeriform state. The former is usually effected by solution in water; the latter by exposure to heat.

Solution.

11. The term, *solution*, is applied to a very extensive class of phenomena. When a solid disappears in a liquid, if the compound exhibit perfect transparency, we have an example of solution. The expression is applied both to the *act* of combination, and to the *result* of the process. When common salt, such as is used in cookery, is agitated with water, it disappears; in other words, its solution takes place; and we also term the liquid which is obtained, a *solution of salt in water.* This is one of the simplest cases that can be adduced of the efficiency of chemical attraction; for solution is always the result of an attraction or affinity, between the fluid and the solid which is acted upon, feeble it is true, yet sufficient in force to overcome the cohesion of the solid. The affinity continues to act until at length a certain point is attained, where the affinity of the solid and fluid for each other is overbalanced by the cohesion of the solid, and the solution cannot be carried farther.

Saturation.

This point is called *saturation*, and the fluid obtained is termed a *saturated solution.* H. 1, 31.

12. The particles of the salt may be regarded as disposed at regular distances throughout the fluid; and if the quantity of water be considerable, the particles will be too far asunder to exert reciprocal attraction; in other words, they will be more powerfully attracted by the water than by each other. If we now slowly get rid of a portion of the water by evaporation, the saline particles will gradually approach each other, and they will aggregate according to certain laws producing a regular solid of a cubic form.

Evaporation.

13. To recover a salt from its solution, if its solubility does not vary with the temperature of the solvent, as in the instance of common salt, it is necessary to expel a portion of the fluid by heat. This constitutes the process of *evaporation.* H. i. 31.

The figure influenced by rapidity of evaporation.

14. The regularity of the figure obtained will be influenced by the rapidity of the evaporation; if the process be slowly conducted, the particles unite with great regularity; if hurried, the crystals are irregular and confused. In common cases the evaporation may be continued till a pellicle forms upon the surface of the solution, which indicates that the attraction of the saline particles for each other, is becoming superior to their

---

[*] From Κρύσταλλος, Ice.

attraction for the water. The formation therefore, of a superficial pellicle is the common criterion of the fitness of a solution for crystallization; but where the object is to obtain very regular and very large crystals, the evaporation must be much slower, and carried to much less extent; even spontaneous evaporation, or that which takes place at common temperatures, must be resorted to.

Time for stopping artificial evaporation.

Crystals formed by fusion.

15. There are certain bodies which may be dissolved or liquified by heat, and during slow cooling, may be made to crystallize. This is the case with many of the metals, and with sulphur. Some other substances, when heated, readily assume the state of vapour, and during condensation, present regular crystalline forms; such as iodine, benzoic acid, camphor, &c.: and in this way crystals of snow are produced by the cooling of aqueous vapour.

Crystallization of substances whose composition is feeble.

16. Some substances are so easily decomposed by heat, and at the same time retain water with such avidity, that it is impossible to crystallize them by any of the above processes; in these cases crystallization may sometimes be effected by placing the solution under the exhausted receiver of an air-pump, over the surface of sulphuric acid, which, by absorbing the vapour as it rises, causes rapid evaporation without increase of temperature.

Water of crystallization.

17. In the act of separating from the water in which they were dissolved, the crystals of almost all salts carry with them a quantity of water which is essential to the regularity of their form, and cannot be expelled without reducing them to shapeless masses. It is termed their *water of crystallization.* H. i. 32.

18. The hardness, brilliancy, and transparency of crystals, also often depend upon their containing this water, which sometimes exists in them in large quantities. Thus, sulphate of soda, in the state of crystals, contains more than half its weight. Sulphate of lime, in its crystallized form, contains about 20 per cent. of water, which it loses at a red heat, and the crystals crumble down into the white powder called Plaster of Paris. Some salts part with it by simple exposure to dry air, when they are said to *effloresce;* but there are other salts which *deliquesce*, or attract water from the atmosphere. Those crystals which effloresce by exposure to air, may often be conveniently preserved, by slightly oiling their surfaces. The best method is to soak the crystals in oil for a few hours, and then to wipe them and put them up in bottles.

Efflorescence and deliquescence.

Watery fusion.

19. Those crystals in which the water of crystallization is so abundant, as to liquefy them on the application of heat, are sometimes said to undergo the *watery fusion.*

20. Some salts, in consequence probably of their strong attraction for the water that retains them in solution, cannot be brought to crystallize in the ordinary way. In such cases, crystallization may be effected by the addition of substances

having a strong affinity for water, by which its attraction fo the dissolved matters is weakened ; thus alcohol, added to certain aqueous saline solutions, produces a separation of crystals but they are generally small and indistinct.

21. When two salts of different solubilities are present i the same solution, they often may be separated by crystallization, that which is least soluble constituting the earlier crop o crystals.

Crystallization promoted by a nucleus.

22. Crystallization is accelerated by introducing into th solution a nucleus, or solid body, upon which the proces begins; and manufacturers often avail themselves of this circumstance. Thus we see sugar-candy crystallized upon strings and verdigris upon sticks. There are cases in which it is particularly advantageous to put a few crystals of the dissolved sal into the solution, which soon cause a crop of fresh crystals In some instances, if there be two salts in solution, tha will most readily separate of which the crystals have bee introduced.

Method of obtaining perfect crystals.

23. By placing a crystal of the same nature in a saturate solution of a salt ; and turning it daily, so that the differen sides shall be successively exposed to the liquid, very large an perfect crystals may be obtained. This fact was first notice by M. Le Blanc of Paris.

24. A strong saline solution, excluded from the air, will frequently crystallize the instant that air is admitted ; a circumstance unsatisfactorily referred to atmospheric pressure. I other cases, agitation produces the same effect.

Exp.

If we make a saturated solution of Glauber's salt in boilin water, in a small matrass, cork it tight, and allow it to remai at rest till perfectly cool, the solution will remain fluid ; but o withdrawing the cork crystallization will generally commence should it not, the introduction of a small piece of the same sal will usually effect it.

These phenomena seem connected with the doctrine of laten heat, but hitherto they have only been imperfectly investigated in some cases they have been shown by Dr Ure to be affecte by electrical changes. *Quarterly Journal*, Vol. x. p. 6.

Light influences crystallization.

25. The presence of light also influences the process of crystallization. Thus we see the crystals collected in campho bottles in druggists' windows always most copious upon th surface exposed to light ; and if we place a solution of nitre i a room which has the light admitted only through a small hol in the window shutter, crystals will form most abundantl upon the side of the basin most exposed to the aperture throug which the light enters, and often the whole mass of crystal will turn towards it.

Many saline solutions form arborescent crystalline pellicles when left to spontaneous evaporation, which slowly travel u the sides of the basin, and gradually proceed down upon th outside : this process also always begins on the side nearest th light, and is often confined to it. Acetate of lime, exhibits this appearance in a very beautiful manner. *Aikin's Dict.* Art. LIGHT.

Structure of crystallized bodies.

26. We may now proceed to examine the structure of crystallized bodies, upon which the *Theories of Crystallization* are founded. This inquiry exposes a connecting link between the chemical and mechanical properties of bodies.

Assume one form rather than another.

It is commonly observed, that crystallized bodies affect one form in preference to others. The fluor spar of Derbyshire crystallizes in cubes: so does common salt. Nitre assumes the form of a six-sided prism, and sulphate of magnesia that of a four-sided prism. These forms are liable to vary. Fluor spar and salt crystallize sometimes in the form of octoedra; and there are so many forms of carbonate of lime, that it is difficult to select that which most commonly occurs.

All varieties of crystals of the same substance have similar nuclei.

Romé de Lisle referred these variations of form to certain truncations of an invariable primitive nucleus; and Gahn afterwards observed, that when a piece of calcareous spar was carefully broken, all its particles were of a rhomboidal figure. This induced Bergman to suspect the existence of a primitive nucleus in all crystallized bodies. (*Physical and Chemical Essays*, Vol. II. p. 1.) When Haüy entered the field of inquiry, he not only corroborated the opinions of Bergman, and submitted former hypotheses to experimental proof, but traced with much success the laws of crystallization and pointed out the modes of transition from primitive to secondary figures. *Traité de Minéralogie*, Paris, 1801.

Crystals cannot be split smoothly but in certain directions.

27. Every crystal may be divided by means of proper instruments; and, if split in certain directions, presents plane and smooth surfaces. If split in other directions, the fracture is rugged, is the mere effect of violence, and is not guided by the natural joining of the crystal. This fact has been long known to jewellers and lapidaries; and an accidental observation of it proved to the Abbé Haüy, the key of the whole theory of crystallization. By the skilful division of a six-sided prism of calcareous spar, he reduced it to a rhomb, precisely resembling that which is known under the name of Iceland crystal. Other forms of calcareous spar were subjected to the same operation; and, however different at the outset, finally agreed in yielding, as the last product a rhomboidal solid. It was discovered also by Haüy, that if we take a crystal of another kind (the cubic fluor spar, Derbyshire spar for instance,) the nucleus, obtained by its mechanical division, will have a different figure, viz. an octoedron. Other crystallized bodies produce still different forms; which are not, however, very numerous. Those which have hitherto been discovered, are reducible to six; the parallelopiped, fig. 1, which includes the cube, the rhomb, and all the solids which are terminated by six faces, parallel two and two; the tetraedron, fig. 2; the octoedron, fig. 3; the regular hexaedral prism, fig. 4; the

Haüy's primitive forms.

Pl. 1.

dodecaedron with equal and similar rhomboidal planes, fig. 5 and the dodecaedron with triangular planes, fig. 6.

Integral elements.

28. The solid of the primitive form, or nucleus of a crysta obtained by mechanical division, may be subdivided in a direction parallel to its different faces. (All the sections thus produced being similar, the resulting solids are precisely simila in shape to the nucleus, and differ from it only in size, whicl continues to decrease as the division is carried farther. T this division, however, there must be a limit, beyond whicl we should come to particles so small, that they could no longe be divided. At this term therefore, we must stop: and t these last particles, the result of an analysis of the primitiv nucleus and similar to it in shape, Haüy has given the name c the *integrant molecule.* If the division of the nucleus ca be carried on in other directions than parallel to its faces, th integral molecule may then have a figure different from that c the nucleus The forms, however, of the integrant molecul which have hitherto been discovered, are only three; the tetrae dron, fig. 2, the simplest of pyramids; the triangular prism fig. 7, the simplest of prisms: and the parallelopiped, incluc ing the cube and rhomboid, the simplest of solids which hav their faces parallel two and two. With respect to octoedral cry tals there is a difficulty, whether the octoedron, or tetraedro is to be adopted as the primitive form; and, whichsoever t chosen, since neither of them can fill space without leavin vacuities, it is not easy to conceive any arrangement, by whic the particles will remain at rest. To obviate this difficulty, I Wollaston has suggested, that, in such instances, the element ry particles may be perfect spheres; and, by the due applic tion of spheres to each other, he has shown, that a variety crystalline forms may be produced;* viz. the octoedron, tl tetraedron, and the acute rhomboid. If other particles havin the same relative arrangement, be supposed to have the shap of oblate spheroids, the regular rhomboid will be the resultin figure; and if the spheroids be oblong instead of oblate, the will generate prisms of three or six sides. The cube, also, I Wollaston has shown, may be explained by the aggregation spheroidical particles.)

Wollaston's theory.

Mr Daniell's experiments.

29. A method of developing the structure of crystals, by new process which appears greatly superior to that of mecha ical division, has been described by Mr Daniell.† It consists exposing any moderately soluble salt to the slow and regulate action of a solvent. A shapeless mass of alum, for instanc weighing about 1500 grains, being immersed in 15 ounc measures of water and set by, in a quiet place, for a period three or four weeks, will be found to have been more dissolv toward the upper than the lower part, and to have assumed pyramidal form. On further examination, the lower end of tl mass will present the form of octoedrons and sections of octo

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* Phil. Trans. 1813. p. 51.

† Quarterly Journal, i. 24.

Pl. 1.

drons, in high relief and of various dimensions. They will be most distinct at its lower extremity, becoming less so as they ascend, fig. 9. This new process of dissection admits of extensive application. Borax, in the course of six weeks, exhibits eight sided prisms with various terminations; and other salts may be made to unfold their external structure by the slow agency of water, fig. 8. Carbonate of lime, carbonate of strontia, and carbonate of baryta, give also distinct results, when acted upon by weak acids; and even amorphous masses of those metals, which have a tendency to assume a crystalline form, such as bismuth, antimony, and nickel, when exposed to very dilute nitric acid, presented at the end of a few days distinct crystalline forms. Large crystals of sulphate of antimony Mr Faraday has also found, admirably illustrated Mr Daniell's mode of displaying crystalline texture. When such a crystal is introduced into a portion of fused sulphuret, it begins to melt down, but not uniformly, for crystals are left more than half an inch long projecting from it.*

Sulphur

The results of these experiments, when minutely traced and investigated, afford strong confirmation to the theory, that the spheroidical is the true form of the ultimate particles of crystallized bodies. H. 1. 35, 38.

Connexion of crystallization with chemistry.

30. In connexion with chemistry, the theory of crystallization opens a new avenue to the science, and frequently enables us to ascertain directly, that, which, independent of such aids, could only be arrived at by an indirect and circuitous route. We frequently read the chemical nature of substances, in their mechanical forms. To the mineralogist, an intimate acquaintance with crystalline forms and modifications of natural bodies is essentially requisite. Indeed, the theory of crystallization may be considered as one of the great supports of that useful branch of natural history, and it is to the indefatigable exertions of Haüy that much of its present perfection is to be referred. In the arts, the process of crystallization is turned to very valuable account, in the separation and purification of a variety of substances.†

SECTION II. *Heterogeneous Attraction or Affinity.*

Chemical attraction or affinity.

31. We have hitherto considered attraction as disposing the particles of bodies to adhere so as to form masses or aggregates; and in many instances, to arrange themselves according to peculiar laws, and to assume regular geometrical figures.—We are now to regard this power as operating upon dissimilar

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* Jour. of Science and the Arts, xi. 202.

† The instruments used for measuring the angles at which the planes of crystals meet, or incline to each other, are called *goniometers*. For the description of these and the method of using them, see Camb. Nat. Philos. Vol. II. p. 14: Cleaveland's Mineralogy, Chap. 2d. (edit. 1822.) Brooke's Crystallography, p. 25.

particles; as presiding over the composition of bodies; and a producing their chemical varieties. This is CHEMICAL ATTRACTION OR AFFINITY.

Distinguished from Cohesive Attraction.

Result of this Attraction.

32. Chemical affinity, like the cohesive attraction, is effectiv only at insensible distances; but it is distinguished from th latter force, in being exerted between the particles or atoms c bodies of *different kinds.* The result of its action is not a mer aggregate, having the same properties as the separate parts, an differing only by its greater quantity or mass, but a new compound, in which the properties of the components have eithe entirely or partly disappeared, and in which new qualities ar also apparent.

Exp.

33 As a general exemplification of chemical action, we ma take potash and sulphuric acid. Each of these bodies in a separate state is distinguished by peculiar properties. The potas converts the blue colour of vegetable infusions* to green, the aci turns them red. But if we gradually add the potash to the aci we shall obtain a liquid which will have neither the properti of the potash or of the acid; and which will no longer chang the colour of the vegetable infusion, and the taste of which wi have been converted into a bitter one.

Neutralization,

34. In cases of this kind where chemical combination tak place, and the qualities of the component parts of a compour are no longer to be detected in it; the bodies combined a said to *neutralize* each other.

distinguished from Saturation.

35. Neutralization is to be distinguished from saturation, (1 by which we express those weaker combinations where there no remarkable alteration of qualities, as in cases of *solution.*- Water, for example, will dissolve successive portions of co mon salt, or sugar, until at length it refuses to take up mor or is *saturated;* the solution retaining the saline or sweet tas and some other qualities of the salt or sugar. The only phy cal quality that is changed being that of cohesion.

The compound may have distinct properties.

36. In other cases, the properties of the compound diff essentially from those of its component parts, and a series new bodies, possessed of distinct and peculiar characters, produced.

Exp. 1.

Thus when two volumes of nitric oxide gas are mixed wi one of oxygen, an orange-coloured gas results, very sour, a soluble in water, whereas, the gases before mixture were colo less, tasteless and insoluble in water.

Exp. 2.

If into a glass vessel, exhausted of air, be introduced so sulphur, and copper filings, and heat applied so as to melt former, it will presently combine with the latter.

Exp. 3.

If we mix a quantity of iron filings and sulphur, and m them in a crucible we obtain a brittle mass which has prop ties different from those of either of its constituent parts.

Results.

We observe as the results of this attraction between th substances, 1, that the substances produced have not the intermediate properties of their elements but that they present new characters; 2, that in the second experiment much heat and light are evolved during the mutual action; 3, that the substances will unite in certain proportions only.

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* The purple cabbage infused in water affords a convenient and economical liquid for this similar purposes.

Solid products.

37. In liquids and gases, similar changes of properties may be exhibited, and, in many cases, a change of form or state results. Thus the combination of aëriform bodies produces a solid.

Pl. 3. Exp. 53

Into a retort (fig. 48, *a*) introduce a small quantity of liquid ammonia (volatile alkali,) and into another a little muriatic acid, insert the beaks of the retorts into the extremities of a glass cylinder. The gases arising from the muriatic acid and ammonia, pass into the cylinder and unite to form a new solid compound, muriate of ammonia (sal ammoniac.)

Exp.

If to a concentrated solution of muriate of lime, sulphuric acid or a saturated solution of carbonate of potassa be gradually added, a white solid will result.

Gaseous.

38. In other cases the solids are converted into aëriform matter, of which the combustion of gunpowder is a familiar instance.—Gases form a liquid; as when olefiant gas is mixed with chlorine.

Exp.

39. When certain liquids are presented to each other gases are the result, as when to two parts of alcohol we add one part of nitric acid, an effervescence ensues, and aëriform matter is copiously evolved.—Solids also produce liquids;

Liquid. Exp.

Rub together in a mortar a few crystals of Glauber's salt with nitrate of ammonia, the two solids become fluid.

Such operations are not confined to art. Nature presents them on an extended scale; and in connexion with the functions of life, renders them subservient to the most exalted purposes.

40. The new chemical powers that bodies thus acquire in consequence of combination, are often extremely remarkable, and can only be learned by *experiment*. It frequently happens that inert bodies produce inert compounds, and that active substances remain active when combined; but the reverse often occurs: thus oxygen, sulphur, and water, in themselves tasteless and comparatively inert, produce sulphuric acid when chemically combined; and potash, which is a powerful caustic, when combined with sulphuric acid, forms a *salt* possessing little activity.

Other changes produced by Chemical action. Exp.

41. The colours of bodies are altered by chemical action. Into a weak solution of nitrate of copper, drop liquid ammonia, a rich blue colour will be produced. Add gradually, on the end of a glass rod, a little sulphuric acid, the liquid will become colourless.

Exp.

To an infusion of purple cabbage add a few drops of an acid, the colour will be changed to red.—The addition of liquid ammonia, in quantity just sufficient to neutralize the acid, will restore the original colour.

Exp.

The addition of ammonia alone, produces a green colour.

Exp.

Into a small jar of chlorine gas, confined by water, introduce a piece of litmus paper, the colour will be wholly destroyed.

Exp.

When sulphate of copper (blue vitriol), and acetate of lead (sugar of lead) are rubbed together in a mortar ; the new compound has a green colour.

Change of temperature and specific gravity.

42. The specific gravity and the temperature of bodies are altered by chemical action.

Exp.

When equal parts of sulphuric acid and water are mixed, the resulting liquid has a specific gravity much above the mean; the temperature is also so much increased that if the mixture be made in a phial about which tow is wrapped containing a small piece of phosphorus, the phosphorus will be inflamed.

Ignition.

43. Ignition is a frequent attendant upon chemical action, (36.)

Exp.

Mix, cautiously, a small quantity of sugar with about half its weight of the salt called chlorate of potash ; drop upon the mixture, from the extremity of a glass rod, a little sulphuric acid, it will be inflamed.

Chemical action takes place between elementary matter is therefore opposed to simple cohesion.

44. As chemical action takes place among the ultimate or constituent elements of bodies, it must obviously be opposed by the cohesion of their particles, and chemical attraction is often prevented by mechanical aggregation.

Exp.

Introduce a piece of the metal antimony into a jar of chlorine gas, it will be only slowly and superficially acted upon ; but if the mechanical aggregation be previously diminished, by reducing the metal to powder, it in that state rapidly unites with the gas, and burns the instant that it is introduced.

Exp.

The influence of mechanical division in promoting the action of chemical affinity and in favouring solution will be obvious, if into a vessel containing dilute muriatic acid we drop a lump of marble ; and into another vessel containing the same acid we pour an equal weight of marble reduced to powder.

Chemical action promoted by Caloric,

45. The chemical energies of bodies, are increased by heat.

Exp.

To four ounce-measures of water, at the temperature of the atmosphere, add three ounces of sulphate of soda in powder, only part of the salt will be dissolved, even after being agitated some time. Apply heat, and the whole of the salt will disappear.

To this law, however, there are several exceptions ; for many salts are equally, or nearly equally, soluble in cold as in hot water ; as will be seen hereafter.

The effects of heat are sometimes only referable to the diminution of adhesion by expansion, or liquefaction ; but in othe cases they are peculiar and complicated and probably concerned in modifying the electrical energies of the acting substances.

46. Mechanical agitation, also favours the chemical action o bodies.

and by Mechanical agitation.

Exp.

Into a wine glass full of water, tinged blue with the infusion of litmus let fall a small lump of solid tartaric acid. The acid, i left at rest, even during some hours, will only change to red that portion of the infusion, which is in immediate contact with it. Stir the liquid, and the whole will immediately become red.

47. An important law of affinity which is the basis of almost all chemical theory, is that one body has not the same force of affinity towards a number of others, but attracts them unequally; or different bodies are possessed of different attractive powers, and if several be brought together, those which have the strongest mutual affinities enter first into union.

Exp.

Thus, if nitric acid be poured upon a mixture of lime and magnesia, it dissolves the former in preference to the latter earth.

Some bodies have no affinity for each other.

48. Some bodies have no affinity for each other. Oil and water, or powdered chalk and water, may be agitated together, but they will not combine. On allowing the vessels containing them to remain at rest, the oil or water rises to the surface, and the mercury, or chalk falls to the bottom.

Union promoted by a third body.

49. The intervention of a third body will sometimes promote the union of two other bodies which have no affinity for each other. Thus oil and water unite immediately on adding an alkali, as caustic potash. The alkali acting as an intermedium. The fact indeed, admits of being explained by the supposition, that the oil and alkali form, in the 1st instance a compound which is soluble in water. (H.)

Exp.

or destroyed.

50. It very frequently happens, on the contrary, that the tendency of two bodies to unite, or remain in combination together, is weakened or destroyed by the addition of a third. Thus alcohol unites with water in such a manner as to separate most salts from it.

Exp.

A striking instance of this is seen in a saturated or strong solution of nitre in water. If to this there be added an equal measure of alcohol, the greater part of the nitre instantly falls down. (U. 187.)

Affinity how inferred.

51. The affinity existing between any two bodies, is inferred from their entering into chemical combination and that this has happened, a change of properties may be considered as a sufficient proof, even though the change may not be very obvious and may require accurate examination to be perceived at all.—H. 1. 41.)

Simple or elective Attraction.

52. The knowledge of the affinities which bodies have for each other, enables us to separate them when united, or to perform the process of *decomposition*. Thus if into a solution of nitrate of silver (lunar caustic) we place a piece of polished copper, it will soon be covered with metallic silver and the solution will have been *decomposed*, and the silver *precipitated*.

Exp.

53. From a great number of facts of this nature, it is clearly ascertained, not as a probable hypothesis, but as a simple matter of fact, that some bodies have a stronger tendency to unite than others; and that the union of any substance with another will exclude, or separate, a third substance which might have been

previously united with one of them; excepting in those wherein the new compound has a tendency to unite with third substance, and form a triple compound. This prefe of uniting, which a given substance is found to exhibit regard to other bodies, has been called *elective* attracti (U. 187.)

Tables of Attraction.

54. Upon this principle, tables of attraction have been structed, the substance whose affinities are to be repres being placed at the head of a column, and the bodies which it combines beneath it, in the order of their respe attractions (see *Brande's History of Chemistry*, p. 78;) the affinity of sulphuric acid for several substances (or would be shown as follows:

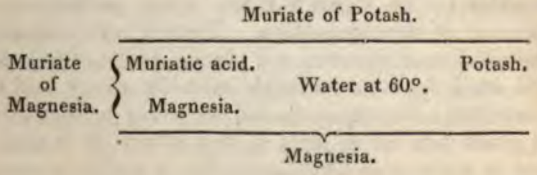
Sulphuric Acid.

Baryta.
Strontia.
Potassa.
Soda.
Lime.
Magnesia.
Ammonia.

From this table it would appear that baryta separates phuric acid from its compounds with all the inferior substa and that ammonia is separated by all that are above it; are, however, many circumstances which interfere wit usefulness and accuracy of such tables, and in some cases are anomalies in the mutual agencies of bodies which w subvert the usual order of arrangement. One of thes been pointed out by Mr R. Phillips,—(*Quarterly Jou* Vol. i. p. 80.) He found that on boiling carbonate of b in a solution of sulphate of potassa, sulphate of baryta an bonate of potassa were formed; and he also found that, o versing the experiment, by boiling sulphate of baryta in tion of carbonate of potassa, carbonate of baryta and sul of potassa were produced.

Bergman's form.

55. Simple decomposition may be expressed also by an form, contrived by Bergman. Thus, the following sc illustrates the decomposition of muriate of magnesia by pot



The original compound (muriate of magnesia) is plac the outside and to the left of the vertical bracket. Th cluded space contains the original principles of the comp and also the body which is added to produce de Above and below the horizontal line are placed of their action. The point of the lower horizonta turned downwards, denotes that the magnesia falls precipitated; and the upper line, being perfec shows, that the muriate of potash remains in soluti the bodies had remained in solution, they woul been placed above the upper line; or, if both had l tated, beneath the lower one. If either one or both in a volatile form, this would have been expresse the volatilized substance above the diagram, and wards the middle of the upper horizontal line. But compositions vary under different circumstances, it is to denote, by the proper addition to the scheme, that the bod are dissolved in water of the temperature of 60°. H. 1. 54.

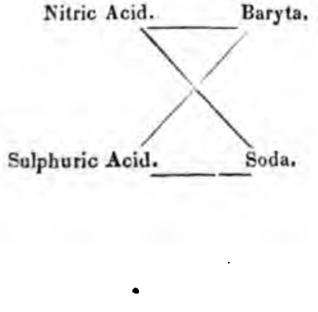
56. Decomposition is effected under a variety of circun tes, and by many methods; but it is commonly descri chemists as SIMPLE and COMPLEX, or SINGLE and DOU

57. In cases of simple attraction or affinity, one body another from its combination with a third. Thus whe is added to a solution of sulphate of zinc (composed of acid and oxide of zinc,) the oxide of zinc is sep sulphate of potassa is produced.

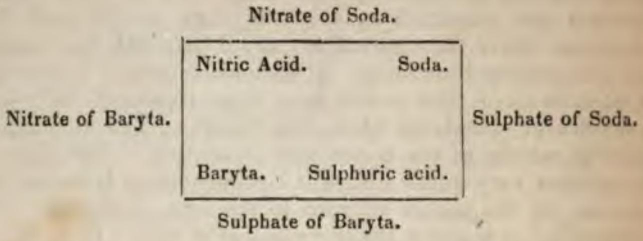
58. In cases of double decomposition, two new compou produced; as when a solution of nitrate of baryta, is with a solution of sulphate of soda, the results are a precipitate of sulphate of baryta, and a solution of nitrate of soda. **Double decomposition.**

In a watery solution of sulphate of zinc (white vitriol) immerse a thin sheet of lead; the lead will remain unaltered, as also will the sulphate of zinc, because zinc attracts sulphuric acid more strongly than lead. But let a solution of acetate of lead be mixed with one of sulphate of zinc; the lead will then go over to the sulphuric acid, while the zinc passes to the acetic. The sulphate of lead being insoluble, will fall down in the state of a white powder; but the acetate of zinc will remain in solution. (H.) **Exp.**

59. These cases of double decomposition are sometimes conveniently illustrated by diagrams, which may either be constructed so as merely to show the result of the change, or where required they may also exhibit the composition of the acting bodies. In the case just alluded to (58) the substances before mixture are shown by parallel lines, and after mixture by diagonal lines.



Or a more complete view of the change is given in the following diagram, where the bodies before mixture are placed upon the outside of the perpendicular lines; their component parts are shown within them; and the new results on the outside of the horizontal lines.



Chemical affinity governed by definite laws.

60. It is obvious, from the uniform results of chemical action that affinity must be governed by certain definite laws, by which its results are determined, and upon which its uniformity depends. Attention was first called to this subject by Mr Higgins in 1789,—(*Comparative View of the Phlogistic and Antiphlogistic Theories.*) He conceived that chemical attraction only prevailed between the ultimate particles of simple elementary matter, and between compound atoms; and, in applying this idea to chemical theory, he expressed by numbers the relative forces of attraction subsisting between the different kinds of ultimate particles and atoms of matter.

Higgins' idea.

Made a system or theory by Dalton.

61. These views were subsequently extended and improved by Mr Dalton, and have since engaged the attention of some of the most eminent chemical philosophers; among whom we may enumerate Gay-Lussac, Berzelius, Davy, Wollaston, Thomson and Brande.

62. In the chemical combination of bodies with each other we remark.

1st. Some bodies unite in all proportions; for example, water and sulphuric acid, or water and alcohol.

2dly. Other bodies combine in all proportions, as far as a certain point, beyond which, combination no longer takes place Thus water will take up successive portions of common salt until at length it becomes incapable of dissolving any more. I cases of this sort, as well as in those included under the firs head, combination is weak and easily destroyed, and the qualities which belonged to the components in their separate stat continue to be apparent in the compound.

3dly. There are many examples in which bodies unite i one proportion only; and in all such cases the proportion o the elements of a compound must be uniform for the *species.*— Thus hydrogen and oxygen unite in no other proportions tha those constituting water. In cases of this sort the combinatio is generally energetic; and the characteristic qualities of th components are no longer observable in the compound.

r that denoting the smallest proportion. In other words,
smallest proportion in which B combines with A, be
l by 10, A may combine with twice 10 of B, or with
imes 10, and so on; but with no intermediate quantities.
cannot be a more striking instance of this law than that
nentioned, of the compounds of manganese with oxygen;
h the oxygen of the three last compounds may be observ-
e a multiplication of that of the first (14) by the numbers,
nd 4.

Atomic theory.

icts of this kind, Mr Dalton has founded what may be term-
Atomic Theory of the chemical constitution of Bodies.
Though we appear when we effect the chemical union
es, to operate on *masses*, yet it is consistent with the
ational view of the constitution of bodies to believe, that
nly between their *ultimate particles*, or atoms, that
ation takes place. By the term *atoms*, it has been
stated, we are to understand the smallest parts of which
are composed. An atom therefore, must be mechanically
ible, and of course a fraction of an atom cannot exist.—
er the atoms of different bodies be of the same size, or of
t sizes, we have no sufficient evidence.

Taking for granted that combination takes place between
ms of bodies only, Mr. Dalton has deduced, from the
weights in which bodies unite, the relative weights of
ltimate particles or atoms. When only one combination
two elementary bodies exists, he assumes, unless the con-
an be proved, that its elements are united atom to atom
Combinations of this sort he calls *binary*. But if
compounds can be obtained from the same elements, they
e, he supposes, in proportions expressed by some simple
e of the number of atoms. The following table exhibits
of these combinations:

m of A + 1 atom of B = 1 atom of C, binary.

The compound atoms he divides again into three different species, namely 1st, atoms formed of only two elementary substances united, or *compound atoms of the first order :* 2dly, atoms composed of more than two elementary substances; and these, as they are only found in organic bodies, or bodies obtained by the destruction of organic matter, he calls *organic atoms :* 3dly, atoms formed by the union of two or more compound atoms; as for example, the salts. These he calls *compound atoms of the second order.* H. 1. 44.

Relative weights of atoms, how ascertained.

67. In adopting the atomic theory, it is important to ascertain the relative weights of the atoms of bodies.

As an illustration of the mode in which this is effected, let us suppose that any two elementary substances, A and B, form a binary compound; and that they have been proved experimentally to unite in the proportion, by weight, of 5 of the former to 4 of the latter; then, since, according to the hypothesis, they unite particle to particle, those numbers will express the relative weights of their atoms. But, besides combining atom to atom singly, 1 atom of A may combine with 2 of B, or with 3, 4, &c. Or 1 atom of B may unite with 2 of A, or with 3, 4, &c. When such a series of compounds exists, the relative proportion of their elements ought necessarily, on analysis, to be proved to be 5 of A to 4 of B; or 5 to (4+4=) 8; or 5 to (4+4+4=) 12, &c.; or, contrariwise, 4 of B to 5 of A; 4 to (5+5=) 10; or 4 to (5+5+5=) 15. Between these there ought to be no intermediate compounds; and the existence of any such (as 5 of A to 6 of B, or 4 of B to 7¼ of A) would, if clearly established, militate against the hypothesis.

Verified.

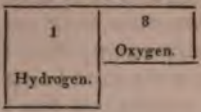
68. To verify these numbers, it may be proper to examine the combinations of A and B with some third substance, for example, with C. Let us suppose that A and C form a binary compound, in which analysis discovers 5 parts of A and 3 of C. Then, if C and B are, also, capable of forming a binary compound, the relative proportion of its elements ought to be 4 of B to 3 of C; for these numbers denote the relative weights of their atoms. By extending the comparison to a variety of bodies, a scale of the relative weights of their atoms may be obtained.

In several instances, additional evidence is acquired of the accuracy of the weight, assigned to an element by our obtaining the same number from the investigation of several of its compounds. H. 1. 47.

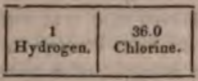
Definite Proportions.

69. The law, that when bodies unite so as to form one compound only, that compound always contains the same relative proportions of its components; and where two bodies unite in more than one proportion, the second, third, *&c.*, proportions are multiples or divisors of the first is well exhibited in the combinations of gaseous bodies. These are seen to unite in simple ratios of volume. Water is composed of hydrogen and oxygen, and 1 part by weight of the former gas, unites to 8 of

the latter. The specific gravity of hydrogen compared with that of oxygen, is as 1 to 16; it is obvious, therefore, that one volume of hydrogen unites to half a volume of oxygen, and that the composition of water will be represented by weight and volume thus.



Muriatic acid gas consists of 1 part by weight of hydrogen and 36.0 by weight of chlorine. The relative specific gravities of these gases are as 1 to 36.0. It is obvious, therefore, that they combine in equal volumes, and that muriatic acid gas may be thus represented:



Carbonic acid unites to potassa in two proportions, and forms two definite compounds. In the one, 70 parts of potassa are combined with 30 of carbonic acid; in the other, 70 of potassa are united to 60 of carbonic acid.

Atomic weights refered to some body as the unit.

70. Chemists have found it convenient to refer the atomic weight of different bodies to some standard, which is assumed as the weight of an atom of some well known substance. Two bodies have been selected for this purpose, viz. oxygen and hydrogen. These bodies, as has been observed (65), unite to form water in the proportions of 8 to 1; If we suppose therefore that this compound is formed by the combination of 1 atom of each element and if we represent the weight of the atom of oxygen by 1, we shall have for the weight of the atom of hydrogen $\frac{1}{8}$ or ,125. If on the contrary we represent the weight of the atom of hydrogen by 1, that of oxygen must be 8. Some chemists, however, have supposed water to be formed of 2 atoms of hydrogen, united to one of oxygen, because there are two volumes of the former and one of the latter, and they consider the volumes of these gaseous bodies as representing atoms. In this case oxygen will be represented by 1, and hydrogen by $\frac{1}{16}$ or ,0625; or if we represent hydrogen by 1, oxygen will be 16. Drs Thomson and Wollaston and Professor Berzelius have assumed oxygen as the unit, while Sir H. Davy, Dalton, Henry, Brande and others have assumed hydrogen as the unit, and have refered the weights of the atoms of other bodies to this as the standard.

71. All cases of chemical combination, in which the qualities of the component parts are no longer to be detected in the compound, or in which a neutral body is produced, are obedient to these laws of union: But in some instances bodies may be said to unite in all proportions, as water and alcohol, *&c.* Other

bodies combine in all proportions, up to a certain point only, and beyond that, combination no longer ensues. Thus water will take up successive portions of common salt, until at length it refuses to take up more, or is *saturated;* and this always occurs when the water has dissolved a definite weight of the salt.

Saturation.

Neutralization.

72. It has been remarked (34) that when bodies mutually disguise each others properties, they are said to *neutralize* each other: an effect especially exemplified in the union of acids and alkalis. The resulting compound being termed a *neutral salt.*

Now when we have ascertained the proportion in which any two or more bodies of one class, a, b, c neutralize another body x of a different class, it will be found that the same relative proportion of a, b, c, will be required to neutralize any other body of the same class as x. Thus since 100 parts of sulphuric acid, and 68 (omitting fractions) of muriatic acid, neutralize 118 of potash, and since 100 of sulphuric neutralize 71 of lime, we may infer that 68 of muriatic acid will also neutralize 71 of lime.

Equivalents.

73. If the quantities of two bodies A and B, that are necessary to saturate a given weight of a third body, be represented by q and r, these quantities may be called *equivalents.* Thus in the above example 100 parts of sulphuric acid and 68 of muriatic acid, are *equivalents* of each other. A column of equivalent numbers of great use in chemical calculations, will be found in the tables intended to accompany this work. By adapting a table of this sort to a moveable scale, on the principle of Gunter's sliding rule, Dr Wollaston has constructed a *logometric scale of chemical equivalents,* which is capable of solving with great facility many problems of chemistry.—*Phil. Trans.* 1824.*

Modes of ascertaining the composition of bodies.

74. The proof, which establishes the nature of chemical compounds, is of two kinds, *synthesis* and *analysis.* Synthesis consists in effecting the chemical union of two or more bodies; and analysis, in separating them from each other, and exhibiting them in a separate state. The composition of sulphate of copper (blue vitriol) is *synthetically* demonstrated by *uniting* sulphuric acid to oxide of copper. When we have a compound of two or more ingredients, which are themselves compounded also, the separation of the compounds from each other may be called the *proximate analysis* of the body; and the farther separation of these compounds into their most simple principles, its *ultimate analysis.*

Thus the sulphuric acid of the sulphate of copper consists of sulphur and oxygen, and oxide of copper consists of copper and oxygen; consequently we should say that the *ultimate* component parts of blue vitriol are copper, sulphur, and oxygen.

The proximate analysis of sulphate of potash consists in resolving it into potash and sulphuric acid; and its ultimate analysis is effected by decomposing the potash into potassium and oxygen, and the sulphuric acid into oxygen and sulphur.

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* A Plate of this instrument is given in the *Tables.*

When the analysis of any substance has been carried as far as possible, we arrive at its most simple principles, or *elements;* by which expression we are to understand, not a body that is *incapable* of further decomposition, but only one which *has not yet been decomposed.* The progress of chemical science, for several centuries past, has consisted in carrying still farther the analysis of bodies, and in proving those to be compounded, which had before been considered as elementary. H. 1.

SECTION III. *Heat.*

Sensations of heat and cold.

75. No sensations are more familiar to us than those of heat and cold. They are excited by bodies applied to our organs, and at different times very different degrees of sensation are excited. The same body is capable at one time, of occasioning the feeling of intense cold; in a short time it may convey an agreeable warmth, and by another change of circumstances, it may induce extreme heat. From this it is evident that the power of inducing these sensations does not depend upon the matter itself, which is applied to our organs; for every shade of sensation is produced, without the qualities of that matter being permanently changed; it is considered therefore as depending on the operation of a certain power or subtle principle, present in bodies, and which, according to its quantity, gives rise to the power of exciting different sensations.

Heat a subtle power or principle.

If a piece of iron be made red hot, we conceive that a quantity of what we call *heat,* that is, of a certain subtle power, has entered into it, and that the property the iron in this state has, of affecting the organs of animals in a peculiar manner, depends on the presence of this power. When the iron is left to cool, we suppose that it parts with its excess of heat.

Has received various names.

76. This principle, or power, has been distinguished by various appellations, as Fire, Heat, the matter of Heat, or the Igneous fluid; terms which are either ambiguous, or which involve some hypothesis, and which are superseded by the unexceptionable appellation of Caloric. M. 1. 183.

Definition of Caloric.

77. Or we may define caloric as the agent to which the phenomena of heat and combustion are ascribed. U. 25.

May be considered under two views.

78. Caloric, so far as its chemical agencies are concerned, may be chiefly considered under two views—as an antagonist to the cohesive attraction of bodies—and as concurring with, and increasing elasticity. By removing the particles of any solid to a greater distance, from each other, their cohesive attraction is diminished; and one of the principal impediments to their union with other bodies is overcome. On the other hand, caloric may be infused into bodies in such quantity, as not only to overcome cohesion, but to place their particles beyond the

sphere of chemical affinity. Thus, in the class of substances, called gases, the ponderable ingredient, whether solid or liquid, is dissolved in so much caloric, that, in mechanical properties, the gases agree with the air of our atmosphere, especially in being permanently elastic. Different bodies of this class do not, in general, unite by simple mixture. But if, of two gases, we employ either one or both in a state of great condensation, or compress their particles nearer to each other by any means, the gravitating matter of both unites, and forms a new compound. Thus hydrogen and oxygen gases remain together in a state of mixture for any length of time, without combining; but if we force their particles into a state of contiguity, by sudden and violent mechanical pressure, they unite and compose water. In many cases, also, when two bodies are combined together, one of which is fixed, and the other becomes elastic by union with caloric, we are able, by its interposition alone, to effect their disunion. Thus carbonate of lime gives up its carbonic acid by the mere application of heat.

The state of bodies influenced by caloric.

We may consider, then, all bodies in nature as subject to the action of two opposite forces, the mutual attraction of their particles on the one hand, and the repulsive power of caloric on the other; and bodies exist in the solid, liquid, or elastic state, as one or the other of these forces prevails. Water, by losing caloric, has its cohesion so much increased, that it assumes the solid form of ice; adding caloric, we diminish again its cohesion, and render it fluid; and, finally, by a still farther addition of caloric, we change it into vapour, and give it so much elasticity, that it may be rendered capable of bursting the strongest vessels. In many liquids, the tendency to elasticity is even so great, that they pass to the gaseous form by the mere removal of the weight of the atmosphere. H. 1. 80.

It expands bodies.

79. Expansion is the most obvious and familiar effect of heat; and it takes place though in different degrees, in all forms of matter.—When a body which occasions the sensation of heat on our organs, is brought into contact with another body which has no such effect, the result of their mutual action is that the hot body contracts, and loses to a certain extent its power of communicating heat, and the other body expands, and in a degree acquires this power. D. 1. 70.

Proved by experiment.

The expansion of solids may be made apparent by heating a rod of iron, of such a length as to be included, when cold, between two points, and the diameter of which is such, as barely to allow it to drop through an iron ring. When heated, it will have become sensibly longer; and it will be found incapable of passing through the ring.

Principle upon which pyrometers are made.

80. This property of metals has been applied to the construction of an instrument for measuring temperature, called a *pyrometer*.

Pl. 1. Ferguson's Pyrometer.

An instrument of this kind is represented by fig. 25, which will be found very convenient for showing the expansibilities of the board immediately under the box, to allow the ap- ion of a lamp. The small expansion of the metallic bar is fied by the first lever in the proportion of the distances point of pressure from its plane, and from its other ex- y; and this magnified effect is again magnified by the lever, so that an expansion of the 400th part of an inch ponds to a whole inch on the scale. This pyrometer is to the objection that the distance of the points of pressure he fulcrum and extremity of each lever is variable during periment. (*See Ferguson's Lect.*)

Mr Daniell's pyrometer.

Pl. 2.

Mr Daniell has availed himself of the same property of sion, in constructing a pyrometer fig. 32, for measuring legrees of heat. A bar of platina is enclosed in a case c,) made of the same ware as black lead crucibles, and d to it at one end, while the other is left free to move an (*b*) by which means degrees of heat above ignition admit ng accurately measured.*

Bodies possess different powers of expansion.

The degree of expansion is not the same for all solids, ven differs materially in substances of the same class. the metals expand in the following order, the most ex- le being placed first; zinc, lead, tin, copper, bismuth, teel, antimony, palladium, platina. H. 1. 90.

Solids are less expansible than liquids, and gases or aëri- odies more than liquids.

Expansion of liquids. Pl. 1. Exp.

The expansion of liquids may be shown by the follow- periment. Into a glass vessel, (fig. 11) having a nar- eck, introduce some spirits of wine, and apply the heat

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tremity *a*, is closed, the extremity, *c*, open; *d*, is a ferule of brass into which tha end of lead tube is accurately fitted, and to which the scale *e*, *f*, *g*, *h*, is attached. The bar of within the tube *a*, *b*, *c*, and extending to *b*,) is 10,2 inches long and 0,14 of an inch in diame- immoveably fixed at *a*, by a nut and screw of the same metal on the outside, and a pin or n the inside. It is likewise confined to its place at *b*, by a small perforated plate of platinum hich it passes. From its end *b* proceeds a fine platinum wire of about $\frac{1}{100}$ of an inch and coming out of the tube at *d* passes two or three times round the axis of the wheel *i*, fixed k of the scale *e*, *f*, *g*, *h*. It is then bent back and attached to the extremity of a slight spring h is stretched on the outside of the brass ferule, and fixed by a pin at *n*; the wire is thus of a lamp; or immerse the ball of the vessel in hot water—the spirits of wine will expand and rise in the narrow neck.

Their relative expansibilities different.

85. Liquids differ also in their relative expansibilities: ether is more expansible than spirit of wine, and spirit more than water, and water more than mercury. Those liquids are generally most expansible which boil at the lowest temperature.

Exp.

This may be rendered evident by partially filling several glass tubes of equal diameters, furnished with bulbs, with the different liquids and placing them in hot water, as the liquids expand, they will rise to different heights in the tubes. To render this more apparent the liquids may be tinged with some colouring matter.

Aëriform bodies. Exp.

86. The expansion of aëriform bodies may be shown by filling the body of the vessel (fig. 10) with water and, keeping the finger over the orifice of the neck, inverting it in a vessel of water, the air will rise and occupy the body of the vessel, apply the heat of a lamp, and the air will expand and cause the water to descend in the neck of the vessel.

Exp.

If a bladder filled with air, the neck of which is closely tied, be held before a fire, it will become fully distended, and may even be burst by continuing and increasing the heat.

Rate of expansion among pure gases.

87. In all pure gaseous bodies, the rate of expansion for similar increase of temperature is similar: 100 measures of air, when heated from the freezing to the boiling point of water, suffer an increase in bulk=37,5 parts at mean pressure.

All bodies, after being heated, return again on cooling precisely to their former dimensions.

The experiments of Gay Lussac have proved that steam and all vapours are subject to laws of expansion similar to those of air,—hence the table showing the changes of bulk suffered by 100000 parts of air at all temperatures between 32° and 212° will equally apply to all gases and vapours. *See Tables.*

Fluids with the highest boiling point expand most equally.

88. The expansion of liquids is not equable for equal additions of heat at different temperatures. Thus the addition of 5° of heat to alcohol at 40°, will produce a less relative increase of bulk than the same addition of heat to alcohol of 150°; and in general, the nearer a liquid approaches its boiling point, the greater is its expansibility. Those liquids therefore appear most equably expansible which have the highest boiling points, and hence one of the great advantages of mercury, as will presently be seen, in constructing thermometers.

Specific gravity altered by a change of temperature.

89. As heat increases the bulk of all bodies, it is obvious that change of temperature is constantly producing changes in their density or specific gravity, as may be easily demonstrated in fluids where there is freedom of motion among the particles. If we apply heat to the bottom of a vessel of water, that portion of the fluid, which is nearest to the source of heat, is expanded and becoming specifically lighter, ascends, and is replaced by a colder portion from above. This, in its turn, becomes heated and dilated, and gives way to a second colder portion; and

thus the process goes on, as long as the fluid is capable of imbibing heat. In air, similar currents are continually produced, and the vibratory motion observed over chimney pots, and slated roofs which have been heated by the sun, depends upon this circumstance: the warm air rises, and its refracting power being less than that of the circumambient colder air, the currents are rendered visible by the distortion of objects viewed through them.

Ventilation.

90. The ventilation of rooms and buildings, can only be perfectly effected by suffering the heated and foul air to pass off through apertures in the ceiling, while fresh air, of any desired temperature, is admitted from below. Various contrivances have been resorted to, to prevent the passage of cold air from above downwards through the ventilator, which can only be completely effected by keeping the ventilating tubes at a higher temperature than the surrounding air; heating them, for instance, by steam; passing them through a fire; or placing a lamp beneath them, of sufficient dimensions to cause a strong current upwards.

Exception to the law of expansion by caloric.

91. To the general law of the expansion of bodies by heat and their contraction by cold, there are, however, several exceptions. Water has attained its maximum of density at 40°, and if it be cooled below 40° it expands as the temperature diminishes, as it does when heated above 40°; and the rate of this expansion is equal for any number of degrees above or below its maximum of density, so that the bulk of water at 32° and at 48° will be the same. Accordingly, if two thermometer tubes, one containing spirit of wine, and the other water, be immersed into melting snow, the former will sink till it indicates 32°; but the latter when it has attained 40° begins to expand, and continues so to do till it freezes.

An apparent object in this anomaly.

This anomaly in respect to water is productive of very important consequences, in preserving the depths of rivers and lakes of a temperature congenial to their inhabitants.

Water expands more in freezing than it does when heated from the freezing to the boiling point.

92. There are many liquids which suffer considerable expansion in passing into the solid state. This is the case with the greater number of saline solutions, and remarkably with water; it seems connected with the phenomena of crystallization, and is referable to a new arrangement of particles. That the force with which water expands in the act of freezing is very considerable, is shown by the rupture of leaden and iron pipes in which it is suffered to freeze. Dr Thomson has shown that water in freezing suffers a much greater expansion than when heated from the freezing to the boiling point; for the specific gravity of water at 60° being $= 1$, that of ice at 32° is only 0,92. Of the metals, Reaumur found that cast-iron, bismuth, and antimony, were expanded in becoming solid; the rest contracted.

Principles upon which thermometers are constructed.

93. If we mix equal quantities of the same fluid at different temperatures, the cold portion will expand as much as the hot portion contracts, and the resulting temperature is the mean;

so that it appears, that as much heat as is lost by the one portion is gained by the other. Upon this principle, *thermometers* are constructed. A common thermometer consists of a tube terminated at one end by a bulb, and closed at the other. The bulb and part of the tube are filled with a proper liquid, generally mercury, and a scale is applied, graduated into equal parts. Whenever this instrument is applied to bodies of the same temperature, the mercury, being similarly expanded, indicates the same degree of heat.[*]

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[*] The fluid best adapted for filling thermometers is mercury, which, though it expands less i amount than air, or alcohol, still undergoes this change to a sufficient degree; and, in consequence o its difficult conversion into vapour, may be applied to the admeasurement of more elevated tempera tures. As a considerable saving of expense will accrue to the experimentalist, who is able to construc mercurial thermometers, I shall offer some rules for this purpose. In general, however, I shoul deem it preferable merely to superintend their construction, and to be satisfied, by actual inspectio that the necessary accuracy is observed; because much time must be unavoidably lost, in acquirin the manual skill which is essential to construct them neatly.

Thermometer tubes may be had at the glass-house, and of various philosophical instrument maker In purchasing them, those should be rejected that are not hermetically sealed at both ends; becau the smallest condensation of moisture, which must take place when air is freely admitted within th tube, is injurious to the accuracy of the instrument. A small bottle of elastic gum should be provide in the side of which a brass valve is fixed, or a piece of brass perforated by a small hole, to be occa sionally stopped by the finger. A blow-pipe is also an essential part of the apparatus; and, in add tion to one of the ordinary kind, it will be found useful to have one, which is supplied with air by pair of double bellows, worked by the foot.

Before proceeding to the construction of the thermometer, it is necessary to ascertain, that the tu is of equal diameter in different parts. This is done by breaking off both of the sealed ends, immersi one of them an inch or two deep in clean and dry mercury, and then closing the other end with t finger. On withdrawing the tube from the mercury, a small column of that fluid remains in it, t length of which is to be examined, by laying the tube horizontally on a graduated ruler.[*] By inclini the tube, this column may be gradually moved through its whole length; and if the tube be of unifo bore it will measure the same in every part. Such a degree of perfection, however, is scarcely ev to be observed throughout tubes of considerable length; but, in general, a portion of the tube w be found perfect, of sufficient length for a thermometer, and this part is to be broken off.

On one end of the tube, let the neck of the elastic bottle be firmly tied; and let the other end heated by the flame of the blow-pipe, till the glass softens. The softened part must then be press by a clean piece of metal, into the form of a rounded button; and to this the flame of the lamp m be steadily applied, till it acquires a white heat, and seems about to enter into fusion. To prev its falling on one side, the tube, during this time, must be constantly turned round by the ha When the heated part appears perfectly soft, remove it quickly from the lamp, and holding the t vertically, with the elastic bottle uppermost, press this last gently with the hand. The glass will blown into a small ball, but not into one sufficiently thin for the purpose. To this the flame of lamp must again be applied, turning it quickly round; and on the second or third repetition of process of blowing, the ball will be completely formed. The proportion of the size of the ball to bore of the tube can only be learned by some experience.

To fill the ball, which has been thus formed, with mercury, the air must first be expelled by hold it over the flame of an Argand's lamp, and then quickly immersing the open end of the tube in v clean and dry quicksilver. As the ball cools, the mercury will ascend, and will partly fill it. L paper funnel be tied firmly over the open end of the tube; into this pour a small portion of quicksil and apply the heat of the lamp to the ball. Any remaining portion of air will thus be expelled; ar the heat be raised so as to boil the mercury, the ball and stem will be filled with mercurial vapour, condensation of which, on removing the ball from the lamp, will occasion a pretty complete vac Into this vacuum, quicksilver will descend from the paper cone; and the instrument will be comple filled. But for the purpose of a thermometer, it is necessary, that the mercury should rise only certain height of the stem; and a few drops may, therefore, be expelled by cautiously applying heat of the lamp. To estimate whether the proper quantity of quicksilver has been left in the in ment, immerse the ball, first in ice-cold water, and then in the mouth. The space between these points will comprise about 64 degrees, or rather more than one-third of the whole space between

[*] If the tube be of an extremely small bore, the mercury will not enter, and must be drawn i the action of the elastic bottle, and not by the mouth.

94. In dividing the scale of a thermometer, the two fixed points usually resorted to are the freezing and boiling of water, which always takes place at the same temperature, when under the same atmospheric pressure. The intermediate part of the scale is divided into any convenient number of degrees; and it is obvious, that all thermometers thus constructed will indicate the same degree of heat when exposed to the same temperature. In the centigrade thermometer, this space is divided into 100°; the freezing of water being marked 0°, the boiling point 100°. In this country we use Fahrenheit's scale, of which the 0° is placed at 32° below the freezing of water, which, therefore, is marked 32°, and the boiling point 212°, the intermediate space being divided into 180°. Another scale is Reaumur's; the freezing point is 0°, the boiling point 80°. These are the principal thermometers used in Europe and this country.

Rules for comparing the ordinary thermometers.

95. Each degree of Fahrenheit's scale is equal to ⅘ths of a degree on Reaumur's: if, therefore, the number of degrees on Fahrenheit's scale above or below the freezing of water be multiplied by 4 and divided by 9, the quotient will be the corresponding degree of Reaumur.

Fahrenheit. Reaumur.

$$68°—32°= 36\times4=144\div9=16°$$
$$212°—32°=180\times4=720\div9=80°$$

freezing and boiling points of water. If the empty part of the tube exceeds, in length, about three times the portion thus filled by the expanded quicksilver, we may proceed (when an instrument is wanted with a scale including only from 32° to 212°) to seal it hermetically, which is done as follows: The part to be sealed, is first heated with a blow-pipe, and drawn out to a fine capillary tube: the bulb is then heated till a few particles of quicksilver have fallen from the top of the tube: at this moment, the flame of another candle is directed, by the blow-pipe, on the capillary part of the tube, the candle is withdrawn from the ball, and the tube is sealed, at the instant when the mercury begins to descend. If this operation has been skilfully performed, so as to leave no air in the tube, the whole of the tube should be filled with quicksilver on holding the instrument with the ball uppermost.

To have very large degrees, the ball must bear a considerable proportion to the tube; but this extent of scale cannot be obtained without sacrificing, in some measure, the sensibility of the instrument.* The whole of the process of constructing thermometers neatly and accurately is connected with the possession of manual skill, which practice only can confer; and it is scarcely possible, without the most tedious minuteness, to describe all the necessary precautions and manipulations. These will readily suggest themselves to a person who carries the above instructions into effect.

In graduating thermometers, the first step consists in taking the two fixed points. The freezing point is ascertained by immersing in thawing snow or ice, the ball and part of the stem; so that the mercury, when stationary, shall barely appear above the surface. At this place let a mark be made with a file. In taking the boiling point, considerable caution is required; and, for reasons which will afterwards be stated, attention must be paid to the state of the barometer, the height of which, at the time, should be precisely 29,8. A tin vessel is to be provided, (for according to Gay Lussac,† one of glass leads to erroneous results,) four or five inches longer than the thermometer, and furnished with a cover, in which are two holes. Through one of these, the thermometer stem must be passed, (the bulb being within the vessel,) so that the part, at which the boiling point is expected, may be just in sight. The other hole may be left open, and the cover being fixed in its place, the vessel, containing a few inches of water at the bottom, is to be set on the fire. The thermometer will presently be wholly surrounded by steam; and when the mercury becomes stationary in the stem, its place must be marked. The scale of Fahrenheit is formed by transferring the intermediate space to paper by a pair of compasses, and dividing it into 180°, the lowest being called 32° and the highest 212°. H. 1. 94.

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* Directions for constructing thermometers of great sensibility are given by the Chevalier Landriani in the 7th vol. of the Journal of Science, p. 183.

† 82 An. de Ch. 174, and 7 An. de Ch. et Phys. 307.

To reduce the degrees of Reaumur, to those of Fahrenheit, they are to be multiplied by 9, and divided by 4.

Reaumur. Fahrenheit.

$$16^\circ\times9=144\div4=36^\circ+32^\circ=68$$

$$80^\circ\times9=720\div4=180^\circ+32^\circ=212$$

Every degree of Fahrenheit's is equal to $\frac{5}{9}$ of a degree on the centigrade scale ; the reduction, therefore, is as follows :

Fahrenheit. Centigrade.

$$212-32=180\times5=900\div9=100^\circ$$

Centigrade. Fahrenheit.

$$100\times9=900\div5=180+32=212^\circ$$

Advantage of spirit of wine.

96. When a thermometer is intended to measure very low temperatures, spirit of wine is employed in its construction, as that fluid has never been frozen, whereas the low temperature at which it boils renders it unfit for measuring high temperatures. Quicksilver will indicate 500°, but freezes at 40°.

Air thermometer of Sanctorio.

Pl. 1.

97. Air is sometimes resorted to as indicating very small changes of temperature. The instrument employed by Sanctorio, to whom the invention of the thermometer is generally ascribed, was of a very simple kind, and measured variations of temperature by the variable expansion of a confined portion of air. To prepare this instrument, a glass tube (fig. 12) is to be provided, eighteen inches long, open at one end, and blown into a ball at the other. On applying a warm hand to the ball, the included air expands, and a portion is expelled through the open end of the tube. In this state, the aperture is quickly immerse in a cup filled with any coloured liquid, which ascends into the tube, as the air in the ball contracts by cooling. The instrumen is now prepared. An increase of temperature forces the liquo down the tube ; and, on the contrary, the application of cold causes its ascent. These effects may be exhibited, by alternatel applying the hand to the ball, and then blowing on it with a pai of bellows. By the application of a graduated scale, the amoun of the expansion may be measured.

Air thermometer for liquids.

The ball of the instrument, it must be obvious, cannot b conveniently applied to measure the temperature of liquids. Fo adapting it to this purpose, a slight variation may be made in it construction, as represented fig. 27. To prepare this instrument a small spherical glass vessel is to be about one 6th or one 4t filled with any coloured liquid. The tube, open at both ends, i then to be cemented into the neck, with its lower aperture beneath the surface of the fluid. The expansion of the include air drives the liquid up the stem, to which we may affix a graduated scale, corresponding with that of a common mercuria thermometer. Other modifications have also been made by different philosophers. One of the most useful and simple form is represented fig. 28. It consists merely of a tube of ver small bore, from 9 to 12 inches long, at one end of which is blown a ball, from half an inch to an inch in diameter, which is afterwards blackened by paint, or by the smoke of a candle. A small column of coloured liquid, about an inch in length, is then introduced, by a manipulation similar to that already described. To fit the instrument for use, this column ought to be stationary, about the middle of the tube, at the common temperature of the atmosphere. The slightest variation of temperature occasions the movement of the coloured liquid; and a scale of equal parts measures the amount of the effect.

An insuperable objection, however, to the air thermometer, *as thus constructed*, is, that it is effected, not only by changes of temperature, but by variations of atmospheric pressure. Its utility consists in the great amount of the expansion of air, which, by a given elevation of temperature, is increased in bulk above twenty times more than mercury. Hence it is adapted to detect minute changes of temperature, which the mercurial thermometer would scarcely discover, and its expansions being uniform for equal additions of heat, it is better adapted than any liquid for becoming, when properly applied, an accurate measure of temperature. Objection to their use.

98. An important modification of the air thermometer has been invented by Mr Leslie, and employed by him, with great advantage, in his interesting researches respecting heat. To this instrument, he has given the name of the *Differential Thermometer*, fig. 13. It consists of two large glass bulbs containing air, united by a tube twice bent at right angles, containing coloured sulphuric acid. When a hot body approaches one of the bulbs, it drives the fluid towards the other. The great advantage of this instrument in delicate experiments is, that general changes of the atmosphere's temperature do not affect it, but it only indicates the *difference* of temperature between the two balls. Leslie's differential thermometer.

99. A differential thermometer has been contrived by Dr Howard resembling that of Mr Leslie in its general form, fig 16, but in which the degree of heat is measured by the expansive force of the vapour of ether or spirit of wine *in vacuo*. Directions for constructing it are given in the 8th vol. of the Quarterly Journal of Science, p. 219. It is intended to be applied to the same purposes as that of Mr Leslie, but is more sensible to changes of temperature, and the movement of the fluid (ether tinged by a drop of tincture of cochineal), follows instantaneously the application of the heating cause, whereas in the air thermometer some time is required before the effect takes place. H. 1. 94. Howard's.

100. The relative quantities of heat which different bodies in the same state require to raise them to the same thermometric temperature, is called their *specific* heat, and those bodies which require most heat are said to have the greatest *capacity* for heat. That the quantity of heat in different bodies of the same temper- Specific caloric. Capacity.

ature is different, was first shown by Dr Black, in his lectures at Glasgow in 1762.

Proof of the accuracy of thermometers.

101. It has been stated (93) as a proof of the accuracy of the thermometer, that equal volumes of the same fluid, at different temperatures, give the arithmetical mean, on mixture. Thus, the temperature of a pint of hot and a pint of cold water is, after mixture, as near as possible half-way between the extremes. The cold water being of a temperature of 50°, and the hot of 100°, the mixture raises the thermometer to 75°. But if a pint of quick-silver at 100° be mixed with water at 50°, the resulting temperature is not 75°, but 70°; so that the quicksilver has lost 30°, whereas the water has only gained 20°. Hence, it is said, that the capacity of mercury for heat is less than that of water; and if the weight of two bodies be compared, which are as 13,3 to 1, their capacities will be to each other as 19 to 1.

Water the standard for specific heat.

Formula for determining the specific caloric of bodies.

102. In cases where the specific heat of bodies is to be ascertained, it is convenient that water should be the standard of comparison, or=1. The following is a general formula for determining the specific heat of bodies, from the temperature resulting from the mixture of two bodies at unequal temperatures, whatever be their respective quantities. Multiply the weight of the water by the difference between its original temperature, and that of the mixture: also, multiply the weight of the other liquid by the difference between its temperature and that of the mixture: divide the first product by the second, and the quotient will express the specific heat of the other substance, that of water being = 1. Thus, 20 ounces of water at 105°, mixed with 12 ounceso f spermaceti oil at 40°, produce a temperature of 90°. Therefore, multiply 20 by 15 (the difference between 105 and 90) = 300. And multiply 12 by 50 (the difference between 40 and 90) = 600. Then 300, ÷ 600 $=\frac{1}{2}$, which is the specific heat of oil; that is, water being = 1, oil is = 0,5.

Leslie's method.

103. The capacities of bodies for heat have considerable influence upon the rate at which they are heated and cooled. Those bodies which are most slowly heated and cooled have generally the greatest capacity for heat. Thus, if equal quantities of water and quicksilver be placed at equal distances from the fire, the quicksilver will be more rapidly heated than the water, and the metal will cool most rapidly when carried to a cold place. Upon this principle, Professor Leslie ingeniously determined the specific heat of bodies, observing their relative times of cooling a certain number of degrees, comparatively with water, under similar circumstances.

All atoms seem to have the same capacity for caloric.

M. M. Petit and Dulong have published some important researches on the subject of specific heat, which render it probable that the atoms of all simple substances have exactly the same capacities for heat.

104. Lavoisier and La Place endeavoured to ascertain the specific heat of bodies by the relative quantities of ice which they were capable of thawing, during cooling: thus, if a pint of water

in cooling from 212° to 32° melted a pound of ice, and a pint of oil in passing through the same range of temperature only gave out heat enough to thaw half a pound of ice, it was concluded that the specific heat of water being = 1, that of the oil was = 0,5. The instrument which they employed in these researches, and which is fully described in Lavoisier's *Elements of Chemistry*, is not however, susceptible of accuracy, for Mr Wedgwood has shown that it is scarcely possible to separate the water from the ice.—*Phil. Trans.* Vol. lxxiv.

Lavoisier's method.

105. The capacity of gases and vapours differs with the nature of the gas, and with its density. In gases, dilatation produces cold, and compression excites heat. A thermometer suspended in the receiver of the air-pump sinks during exhaustion, and sudden compression of air produces heat sufficient to inflame tinder. In liquids, too, condensation diminishes capacity for heat; hence the mixture of spirit and water, and of sulphuric acid and water evolves heat. (42) The increased capacity which air acquires by rarefaction has its influence in modifying natural temperatures. The air, becoming rarer as it ascends, absorbs its own heat and hence becomes cold in proportion as it recedes from the earth's surface: thus moisture, rain, or snow are thrown down on the mountain-tops.

Dilatation of gases produces cold, compression heat.

106. Caloric escapes from bodies in two different modes.—Part of it finds its way through space, independently of other matter, and with immeasurable velocity. In this state it has been called radiant heat, or radiant caloric.

Radiant heat.

107. Radiant caloric exhibits several interesting properties. 1. Its reflection. Those surfaces, that reflect light most perfectly, are not equally adapted to the reflection of caloric. Thus, a glass mirror, which reflects light with great effect when held before a blazing fire, scarcely returns any heat, and the mirror itself becomes warm. On the contrary, a polished plate of tin, or a silver spoon, when similarly placed, reflects, to the hand, a very sensible degree of warmth; and the metal itself remains cool. Metals, therefore, are much better reflectors of caloric than glass; and they possess this property, exactly according to their degree of polish.

Reflection of caloric.

108. Caloric is reflected according to the same law that regulates the reflection of light. This is proved by an interesting experiment of M. Pictet; the means of repeating which may be attained at a moderate expense. Provide two reflectors of planished tin, (*a* and *b*, fig. 24), which may be 12 inches diameter, and segments of a sphere of nine inches radius. Parabolic mirrors are still better adapted to the purpose, but their construction is less easy. Each of these must be furnished, on its convex side, with the means of supporting it in a perpendicular position on a proper stand. Place the mirrors opposite to each other on a table, at the distance of from six to 12 feet. Or they may be placed in a horizontal position, as represented in the fourth plate to Sir H. Davy's Chemical Philosophy, an arrangement in some

Pl. 1.

Exp.

respects more convenient. In the focus of one, let the ball of an air thermometer, or (which is still better) one of the balls of a differential thermometer, be situated; and in that of the other, suspend a ball of iron, about four ounces in weight, and heated below ignition, or a small matrass of hot water; having previously interposed a screen before the thermometer. Immediately on withdrawing the screen, the depression of the column of liquid, in the air thermometer, evinces an increase of temperature in the instrument. In this experiment, the caloric flows first from the heated ball to the nearest reflector; from this it is transmitted, in parallel rays, to the surface of the second reflector, by which it is collected into a focus on the instrument. This is precisely the course that is followed by radiant light; for if the flame of a taper be substituted for the iron ball, the image of the candle will appear precisely on that spot, (a sheet of paper being presented for its reception), where the rays of caloric were before concentrated. H. 1. 102.

Exp.

109. When a glass vessel, filled with ice or snow, is substituted for the heated ball, the course of the coloured liquid in the thermometer will be precisely in the opposite direction; for its ascent will show, that the air in the ball is cooled by this arrangement. This experiment, which appears, at first view, to indicate the reflection of cold, presents, in fact, only the reflection of heat in an opposite direction; the ball of the thermometer being, in this instance, the hotter body. "And since heat emanates from bodies in quantities greater as their temperature is higher, the introduction of a cold body into the focus of one mirror, necessarily diminishes the temperature of a thermometer in the focus of the other, in the same manner as a black body, placed in the focus of the one, would diminish the quantity of light in the focus of the other."*

Radiation in elastic media and the Torricellian vacuum.

Pl. 1.

110. Radiation goes on in all elastic media, and in the Torricellian and air-pump vacuum, as may be shown by igniting charcoal by means of the Voltaic battery, placed in the focus of a small mirror confined in the exhausted receiver of the air-pump. Sir H. Davy found that the receiver being exhausted to $\frac{1}{120}$, the effect upon the thermometer in the opposite focus was nearly three times as great as when the air was in its natural state of condensation, fig. 19, *a* is the receiver, *b b* the insulated wires connected with the voltaic apparatus igniting the charcoal in the focus of the upper mirror *c*. In the focus of the lower mirror *d* is the thermometer *e*.

111. The nature of the *surface* of bodies has an important influence over their power of *radiating* caloric.

Heating effect of solar rays with regard to superficial colours.

112. It has long been known, in regard to solar rays, that their heating effect depends much upon the colour of the surfaces upon which they impinge, and that black and dark bodies are more heated than those which are white or of light tints, circumstances dependent upon absorption and reflection.

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*Davy's Chem. Philos. p. 206.

number in seventy-two minutes, if the surface be tarnished with quicksilver. Water, also, enclosed in a clean and polished tin ball, cools about twice more slowly than water in the same ball covered with oiled paper. Blackening the surface with paint, or even a thin coat of varnish, on the same principle, (112) accelerates greatly the rate of cooling. H. 1. 104.

Vessels intended to retain caloric should be clean and metallic.

It is obvious, from these facts, that all vessels intended to retain heat, should be clean, and metallic, for polished metallic surfaces have very low radiating powers; whereas those vessels which are either to receive, or to radiate, should be blackened upon their surfaces. The knowledge of these properties is economically applicable in a variety of cases.

Absorption of caloric influenced by surface.

116. Radiant caloric is *absorbed* with different facility by different surfaces. This is only stating, in other terms, that surfaces are endowed with various powers of reflecting caloric, since the power of absorbing caloric is precisely opposite to that of reflecting it. Hence the best reflectors of heat will absorb the least. It may be proper, however, to offer some illustrations of the principle under this form.

Exp.

Expose the bulb of a sensible thermometer to the direct rays of the sun. On a hot summer's day it will probably rise, in this climate, (Eng.) to 108°.* Cover it with India ink, and again expose it in a similar manner. During the evaporation of the moisture, it will fall; but as soon as the coating becomes dry, it will ascend to 118°, or upwards, of Fahrenheit, or 10° higher than when uncovered with the pigment. This cannot be explained by supposing that the black coating is gifted with the power of retaining caloric, and preventing its escape; because, from experiments already related, it appears, that a similar coating accelerates the cooling of a body to which it is applied.

Absorption of caloric influenced by colour.

117. Colour has considerable influence over the absorption of caloric. This is shown by the following very simple experiment of Dr Franklin.

Exp.

On a winter's day, when the ground is covered with snow, take four pieces of woollen cloth, of equal dimensions, but of different colours, *viz.* black, blue, brown, and white, and lay them on the surface of the snow, in the immediate neighbourhood of each other. In a few hours, the black cloth will have sunk considerably below the surface; the blue almost as much; the brown evidently less; and the white will remain precisely in its former situation. Thus it appears that the sun's rays are absorbed by the dark coloured cloth, and excite such a durable heat, as to melt the snow underneath; but they have not the power of penetrating the white. Hence the preference, generally given to dark coloured cloths during the winter season, and to light coloured ones in summer, appears to be founded on reason. H. 105.

Conducting power of bodies for caloric.

118. When different bodies are exposed to the same source of heat, they suffer it to pass through them with very different

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* Watson's Essays, v. 193.

undergo the same change of temperature; and 1305 seconds, with the same weight of Eider-down. The compression of flocculent substances to a certain extent, renders them still inferior conductors: thus, when the space which in the above experiments contained 16 grains of Eider-down was filled with 32, and then with 64 grains, the times required for the escape of 60 degrees of heat were successively increased from 1305″ to 1472″ and 1615″.

Effect of texture. On the other hand to show the effect of mere *texture*, similar comparative trials were made of the conducting powers of equal weights of raw silk, of ravelings of white taffeta, and of common sewing silk, of which the first has the finest fibre, the second less fine, and the third from being twisted and harder is much coarser. The difference between these three modifications of the same substance is very striking, the raw silk detaining the heat for 1284″, the taffeta ravelings 1169″, and the silk thread only 917″.—Aikin's *Dict.* Art. Caloric.

120. The different conducting powers of bodies in respect to heat, are shown in the application of wooden handles to metallic vessels; or a stratum of ivory or wood is interposed between the hot vessel and the metal handle. The transfer of heat is thus prevented. Heat is confined by bad conductors; hence clothing for cold climates consists of woollen materials; hence, too, the walls of furnaces are composed of clay and sand.—Confined air is a very bad conductor of heat; hence the advantage of double doors to furnaces, to prevent the escape of heat; and of a double wall, with an interposed stratum of air, to an icehouse, which prevents the influx of heat from without.

Sensations of heat and cold. 121. From the different conducting powers of bodies in respect to heat, arise the sensations of heat and cold experienced upon their application to our organs, though their thermometric temperature is similar. Good conductors occasion, when touched, a greater sensation of heat and cold than bad ones. Metal feels cold because it readily carries off the heat of the body; and we cannot touch a piece of metal immersed in air of a temperature moderate to our sense.

Liquids and gases imperfect conductors. 122. Liquids and gases are very imperfect conductors of heat, and heat is generally distributed through them by a change of specific gravity; by an actual change in the situation of their particles. (89.)

Exp. 1. Take a glass tube, eight or ten inches long, and about an inch in diameter. Pour into the bottom part, for about the depth of an inch, a little water tinged with litmus, and fill up the tube with common water, pouring on the latter extremely gently, so as to keep the two strata quite distinct. If the upper part of the tube be first heated, the coloured liquor will remain at the bottom; but if the tube be afterwards heated at the bottom, the infusion will ascend, and will tinge the whole mass of fluid.

Exp. 2. Into a cylindrical glass jar, four inches in diameter, and 12 or 14 deep, let a circular piece of ice be fitted $3\frac{1}{2}$ inches thick, its place, till it is changed into ice. This property of water is one of the most remarkable exceptions to the law, that bodies are expanded by an increase, and contracted by a diminution, of temperature. H. 1. 107.

124. If we apply heat to the upper surface of any fluid, it will with great difficulty make its way downwards.

Exp. Pl. 1.

Let an air thermometer be cemented into a glass funnel supported as represented in fig. 14; cover the bulb of the instrument with water, and upon the surface of the water pour a small quantity of ether. The ether may be inflamed and the air thermometer will not be sensibly affected.

Rumford's experiments.

125. Count Rumford considered fluids as perfect nonconductors of caloric, and that they propagate caloric in one direction, *viz.* upwards in consequence of the motions which it occasions among the particles of fluid. The Count inferred also, that if these motions could be suspended, caloric would cease to pass through water; and with the view of deciding this question, he made the following experiments, which admit of being easily repeated. A cylindrical tin vessel must previously be provided, two inches in diameter, and 2½ inches deep, having a moveable cover, perforated with a small aperture, for transmitting the stem of a thermometer, which is to be inserted, so that its bulb may occupy the centre of the vessel.

Exp.

Fill this vessel with water of the temperature of the atmosphere; let the cover be put in its place; and let the whole apparatus, except the scale of the thermometer, be immersed in water, which is to be kept boiling over a lamp. Observe how long a time is required to raise the water from its temperature at the outset to 180°, and remove it from its situation. Note, also, how long it takes to return to its former temperature.

Exp.

Repeat the experiment, having previously dissolved in the water 200 grains of common starch. The thermometer will now require about half as long again to arrive at the same temperature. A similar retardation, and to a greater amount, is produced by the mixture of eider-down, cotton-wool, and various other substances, which are not chemically soluble in water, and which can diminish its conducting power in no other way than by obstructing the motion of its particles. H. 108.

Fluids imperfect conductors.

126. The more accurate researches of Dalton, Hope, Murray, (*System of Chemistry*, Vol. i.,) and Thomson, (*System of Chemistry*, Vol. i.) have demonstrated that they do conduct, though very imperfectly.

Exp.

Thus, if we carefully pour hot oil upon water in a tall glass jar with delicate thermometers placed at different distances under the surface, it will be found that those near the heated surface indicate increase of temperature: it might here be said that the heat was conducted by the sides of the jar, and so communicated to the water; to obviate such objection Dr Murray made the experiment in a vessel of ice, which being converted into water at 32°, cannot convey any degree of heat above 32°

downwards; yet the thermometers were affected, as in the former trial.

127. Experiments on the conducting power of air are complex and difficult, and the results hitherto obtained are unsatisfactory.

128. Heat has great influence on the *forms* or *states* of bodies. When we heat a solid it becomes fluid or gaseous and liquids are converted into aëriform bodies or vapours. Dr Black investigated this effect of heat with singular felicity, and his researches rank among the most admirable efforts of experimental philosophy, (Black's *Lectures, edited by John Robinson, LL.D.*) During the liquefaction of bodies, a quantity of heat is absorbed, which is essential to the state of fluidity, and which does not increase the sensible or thermometric temperature. Consequently, if a cold solid body, and the same body hot and in a liquid state, be mixed in known proportions, the temperature after mixture will not be the proportional mean, as would be the case if both were liquid, but will fall short of it; much of the heat of the hotter body being consumed in rendering the colder solid, *liquid,* before it produces any effect upon its *sensible temperature.*

Forms and states of bodies influenced by caloric.

129. Equal parts of *water* at 32°, and of *water* at 212° will produce on mixture a mean temperature of 122°. But equal parts of *ice* at 32°, and of water at 212°, will only produce (after the liquefaction of the ice) a temperature of 52°, the greater portion of the heat of the water being employed in thawing the ice, before it can produce any rise of temperature in the mixture. To heat thus *insensible* or *combined*, Dr Black applied the term *latent heat*. The actual loss of the thermometric heat in these cases was thus estimated; a pound of ice at 32° was put into a pound of water at 172°; the ice melted, and the temperature of the mixture was 32°. Here the water was cooled 140°, while the *temperature* of the ice was unaltered; that is, 140° of heat disappeared, their effect being not to increase temperature, but to produce fluidity.

Latent caloric.

130. In all cases of liquefaction caloric is absorbed, and we produce artificial cold, often of great intensity, by the rapid solution of certain saline bodies in water. Upon this principle the action of freezing mixtures depends, some of which may frequently be conveniently and economically applied to the purpose of cooling wine or water in hot climates, or where ice cannot be procured.

Cold produced by rapid solution.

Dilute a portion of nitric acid with an equal weight of water; and, when the mixture has cooled, add to it a quantity of light fresh-fallen snow. On immersing the thermometer in the mixture, a very considerable reduction of temperature will be observed. This is owing to the absorption, and intimate fixation of the free caloric of the mixture by the liquefying snow.

Exp.

Mix quickly together equal weights of fresh-fallen snow at 32°, and of common salt, cooled, by exposure to a freezing atmosphere, down to 32°. The two solid bodies, on admixture,

Exp.

will rapidly liquefy; and the thermometer will sink 32°, or 0; or, according to Sir C. Blagden, to 4° lower.* To understand this experiment, it must be recollected, that the snow and salt, though at the freezing temperature of water, have each a considerable portion of uncombined caloric. Now salt has a strong affinity for water; but the union cannot take place while the water continues solid. In order, therefore, to act on the salt, the snow absorbs all the free caloric required for its liquefaction; and during this change, the free caloric, both of the snow and of the salt, amounting to 32°, becomes latent, and is concealed in the solution. This solution remains in a liquid state at 0, or 4° below 0 of Fahrenheit; but if a greater degree of cold be applied to it, the salt separates in a concrete form.

Exp.

Most neutral salts, also, during solution in water, absorb much caloric; and the cold, thus generated, is so intense as to freeze water, and even to congeal mercury. The former experiment, however, (viz. the congelation of water), may easily be repeated on a summer's day. Add to 32 drachms of water, 11 drachms of muriate of ammonia, 10 of nitrate of potash, and 16 of sulphate of soda, all finely powdered. The salts may be dissolved separately, in the order set down. A thermometer, put into the solution, will show, that the cold produced is at, or below, freezing; and a little water, in a thin glass tube, being immersed in the solution will be frozen in a few minutes. H. 1. 113.

131. The following Table shews the results of some of Mr Walker's experiments on this subject. *See Philos. Trans. for* 1787—88—89—95 *and* 1801.

Table of frigorific mixtures.

Mixtures.	Parts.	Thermometer sinks.
Muriate of ammonia Nitre Water	5 5 16	From 50° to 10°
Nitrate of ammonia Water	1 1	From 50° to 4°
Sulphate of soda Diluted sulphuric acid	5 4	From 50° to 3°
Snow Common salt	1 1	From 32° to 0°
Muriate of lime Snow	3 2	From 32° to—50°
Snow Diluted sulphuric acid Diluted nitric acid	2 1 1	From—10° to—56°
Snow or pounded ice Common salt Nitrate of ammonia	12 5 5	From—18° to—25°
Muriate of lime Snow	3 1	From—40° to—73°
Diluted sulphuric acid Snow	10 8	From—68° to—91°

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* Philosophical Transactions, lxxviii. 281.

0° Fahrenheit, by an artificial mixture of snow and common salt. The pan *c c* is also filled with these materials, and the wooden cover is then put into its place. The vessels are now left till the quicksilver is frozen. A more elegant, but more expensive, apparatus, by Mr Pepys, intended for the same purpose, is figured in an early volume of the Philosophical Magazine. H. 1. 114.

Latent caloric made sensible.

133. When fluids are converted into solids, their *latent* heat becomes *sensible*. Water if kept perfectly free from agitation may be cooled down several degrees below 32°; but, on shaking it, it immediately congeals, and the temperature rises to 32°.

Exp.

134. The evolution of caloric, during the congelation of water is well illustrated by the following experiment of Dr Crawford:—Into a round tin vessel put a pound of powdered ice; surround this by a mixture of snow and salt in a larger vessel; and stir the ice in the inner one, till its temperature is reduced to + 4° Fahrenheit. To the ice thus cooled add a pound of water at 32° One-fifth of this will be frozen; and the temperature of the ice will rise from 4° to 32°. In this instance, the caloric evolved, by the congelation of one-fifth of a pound of water, raises the temperature of a pound of ice 28°. H. 1. 115.

Exp.

If we dissolve sulphate of soda in water, in the proportion of one part to five, and surround the solution by a freezing mixture, it cools gradually down to 31°. The salt, at this point, begins to be deposited, and stops the cooling entirely. This evolution of caloric during the separation of a salt, is exactly the reverse of what happens during its solution. (*Blagden, Philos. Trans.* lxxviii. 290.)

Exp.

When a solution of Glauber's salt is made suddenly to crystallize, its temperature is considerably augmented; and when water is poured upon quicklime, a great degree of heat is produced by the solidification which it suffers in consequence of chemical combination; congelation, therefore, is to surrounding bodies a heating process and liquefaction a cooling process.

Conversion of liquids into the aëriform state.

135. When liquids are heated they acquire the gaseous form, and become invisible elastic fluids, possessed of the mechanical properties of common air. They retain this form or state as long as their temperature remains sufficiently high, but re-assume the liquid form when cooled again. Fill a jar with water heated to 104° and invert it in a vessel of the same. Then introduce a little ether by means of a glass tube closed at one end. The ether will rise to the top of the jar, and, in its ascent will be changed into gas, filling the whole jar with a transparent invisible, elastic fluid. On permitting the water to cool, the ethereal gas is condensed, and the inverted jar again becomes filled with water.

Exp.

Boiling point of fluids different.

136. Different fluids pass into the aëriform state at different temperatures, or their boiling points are different; these are also regulated by the density of the atmosphere. Ether is changed into gas, by diminishing the weight of the atmosphere. Into a

glass tube, fig. 10, about six inches long, and half an inch in diameter, put a teaspoonful of ether, and fill up the tube with water; then, pressing the thumb on the open end of the tube, place it, inverted, in a jar of water. Let the whole be set under the receiver of an air-pump, and exhaust the air. The ether will be changed into gas, which will expel the water entirely from the tube. On re-admitting the air into the receiver, the gas is again condensed into a liquid form.

Exp. Pl. 1.

Altitudes determined by the changes in the boiling points of water.

137. If we diminish atmospheric pressure, we lower the boiling point. When the barometer is at 28 inches, water will boil at a lower temperature than when it is at 31 inches. Water under mean atmospheric pressure boils at 212°. At the top of Mount Blanc, Saussure found that it boiled at 187°, so that the heights of mountains, and even of buildings, may be calculated by reference to the temperature at which water boils upon their summits. The Reverend Mr Wollaston has described to the Royal Society the method of constructing a thermometer of extreme delicacy, applicable to these purposes.—*Phil. Trans.* 1817. In the vacuum of an air pump, fluids boil at temperatures considerably below their ordinary boiling points. Water, for example, which has been removed from the fire, and has ceased to boil, has its ebullition renewed when it is placed under a receiver, the air of which is quickly exhausted by an air-pump. Alcohol and ether, confined under an exhausted receiver, boil violently at the temperature of the atmosphere.

Exp.

Exp.

Example of diminished pressure facilitating ebullition.

138. The following apparently paradoxical experiment also illustrates the influence of diminished pressure in facilitating ebullition. Insert a stopcock securely into the neck of a Florence flask, fig. 18, containing a little water, and heat it over a lamp till the water boils, and the steam freely escapes by the open stop-cock; then suddenly remove the lamp and close the cock. The water will soon cease to boil; but if plunged into a vessel of cold water ebullition instantly recommences, but ceases if the flask be held near the fire: the vacuum in this case being produced by the condensation of the steam.

Exp.

Example of the contrary effect of pressure. Pl. 2.

139. Under increased pressure on the contrary, fluids require a higher temperature to produce their ebullition, as may be shown by the following experiments, fig. 39. *a* is a strong brass globe, composed of two hemispheres screwed together with flanches; a portion of quicksilver is introduced into it, and it is then about half filled with water. *b* is a barometer-tube passing through a steam-tight collar, and dipping into the quicksilver at the bottom of the globe. *c* is a thermometer graduated to about 400°, and also passing through an air-tight collar. *d* is a stopcock, and *e* a large spirit lamp. The whole is supported upon the brass frame and stand *f*. Upon applying heat to this vessel, the stopcock being closed as soon as the water boils, it will be found that the temperature of the water and its vapour increases with the pressure, which is measured by the ascent of the mercury in the barometer-tube. The thermometer under atmospheric

pressure being at 212°, will be elevated to 217° under a pressure of five inches of mercury, and to 242° under a pressure of 30 inches, or thereabouts; each inch of mercury producing by its pressure, a rise of about 1° in the thermometer. The barometer-tube also serves the purpose of a safety-valve, the strength of the brass globe being such as to resist a greater pressure than that of one atmosphere.

Sensible or free caloric made latent. 140. The conversion of a liquid into vapour is always attended with great loss of thermometric heat; and as liquids may be regarded as compounds of solids and heat, so vapours may be considered as consisting of a similar combination of heat with liquids; in other words, a great quantity of heat becomes latent during the formation of vapour.

Exp. Moisten a thermometer with alcohol, or with ether, and expose it to the air, repeating these operations alternately. The mercury of the thermometer will sink at each exposure, because the volatile liquor, during the evaporation, robs it of its heat. In this way, (especially with the aid of an apparatus, described by Mr Cavallo, in the Philosophical Transactions, 1781, p. 509,) water may be frozen, in a thin and small glass ball, by means of ether. Exp. The same effect may be obtained, also, by immersing a tube, containing water at the bottom, in a glass of ether, which is to be placed under the receiver of an air pump; or the ether may be allowed to float on the surface of the water. During the exhaustion of the vessel, the ether will evaporate rapidly, and, robbing the water of heat, will completely freeze it; thus exhibiting the singular spectacle of two fluids in contact with each other, one of which is in the act of boiling, and the other of freezing, at the same moment.

Dr Marcet's method of freezing mercury. By a little modification of the experiment, mercury itself, which requires for congelation a temperature of almost 40° below 0 of Fahrenheit, may be frozen, as was first shown by Dr Marcet. Pl. 3. A conical receiver, fig. 54, open at the top, is placed on the plate of an air-pump, and a small tube with a cylindrical bulb at its lower end, is suspended within the receiver, through the aperture, by means of a brass plate, perforated in its centre, and fitting the receiver air-tight, when laid upon its open neck. The tube passes through this plate, to which it is fitted by leather adjustment, or simply by a cork secured with sealing wax. The bulb is then wrapped up in a little cotton wool, or, wha is better, in a small bag of fine fleecy hosiery, in which a smal spirit thermometer graduated below 40° Fahrenheit, may als be included, and after being dipped into sulphuret of carbon o ether* the apparatus is quickly placed under the receiver, whic is exhausted as rapidly as possible. In two or three minutes the temperature sinks to about 45° below 0, at which momen the quicksilver in the stem suddenly descends with great rapidity. If it be desired to exhibit the mercury in a solid state common tubes may be used, which have originally been about an inch in diameter, but have been flattened by pressure, when softened by the blow-pipe. The experiment succeeds, when the temperature of the room is as high as + 40° Fahrenheit. H. 126.

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* In exhausting a vessel containing either of these fluids, the valves of the air-pump must be m tallic.

Exp.

Immerse a thermometer into an open vessel of water placed over a lamp. The quicksilver rises to 212°, the water then boils, and although the source of heat remains, neither the water nor the steam acquire a higher temperature than 212°; the heat then becomes latent, and is consumed in the formation of steam.

Dr Black's estimate of latent caloric in aqueous vapours.

141. To ascertain the absolute loss of thermometric heat in this case, Dr Black instituted the following experiments: he noted the time required to raise a certain quantity of water to its boiling point; he then kept up the same heat till the whole was evaporated, and marked the time consumed by the process; it was thus computed to what height the temperature would have risen, supposing the rise to have gone on above 212°, in the same ratio as below it; and as the temperature of the steam was the same as that of the water, it was fairly inferred that all the heat above 212° was essential to the constitution of aqueous vapour. Dr Black estimated this quantity at about 810°; that is, the same quantity of heat which is required for the total evaporation of boiling water at 212° would be sufficient to raise the water 810° above its boiling point, or to 1022° had it continued in the liquid state. There are other means of ascertaining the latent heat of steam which lead us to place it between 900° and 1000°. B.

Table of the latent caloric of several fluids by Dr Ure.

142. The following table of the latent heat of steam and some other vapours is extracted from a paper in the *Philosophical Transactions for* 1818, by Dr Ure.

Vapour of	Water at 212° . . .	967°,00
————	Alcohol	442 ,00
————	Ether	302 ,38
————	Petroleum	177 ,87
————	Oil of Turpentine .	177 ,87
————	Nitric acid	531 ,99
————	Liquid Ammonia .	837 ,28
————	Vinegar	875 ,00

Latent heat becomes sensible.

143. When steam is again condensed, or when vapours reassume the liquid state, their latent heat becomes sensible; and in this way it is obvious that a small quantity of steam will, during its condensation, communicate heat sufficient to boil a large quantity of water.

Pl. 2.

The small boiler, represented in fig. 52, taken from Dr Henry's *Elements of Chemistry*, may be conveniently employed in experiments on the latent heat of steam.

For this purpose the tube *e* must be screwed on the stopcock *b*, and immersed into the glass of water *f*. The cock *c* being closed, the steam arising from the boiling water *a* will pass into the cold water *f*, the temperature of which will be much augmented by its condensation. Ascertain the increase of temperature and weight, and the result will show how much a given weight of water has had its temperature raised by a certain weight of condensed steam. To another quantity of water, of the same weight and temperature as that in the jar at the outset of the experiment, add a quantity of water at 212°, equal in weight to the condensed steam; it will be found, on comparing the resulting temperatures, that a given weight of steam has produced, by its condensation, a much greater elevation of temperature than the same quantity of boiling water.—H. 1. 129.

Economical use of steam.

Pl. 1.

144. The large quantity of heat, latent in steam renders its application extremely useful for practical purposes. Thus water may be heated, at a considerable distance from the conducting pipe *e* fig. 52. This furnishes us with a commodious method of warming the water of baths, which, in certain cases of disease, it is of importance to have near the patients bed-room; for the boiler, in which the water is heated, may thus be placed on the ground-floor, or in the cellar of a house; and the steam conveyed by pipes into an upper apartment. Steam may also be applied to the purpose of heating or evaporating water, by a modification of the apparatus. Fig. 52, *g* represents the apparatus for boiling water by the condensation of steam, without adding to its quantity; a circumstance occasionally of considerable importance. The steam is received between the vessel, which contains the water to be heated, and an exterior case; it imparts its caloric to the water, through the substance of the vessel; is thus condensed, and returns to the boiler by the perpendicular pipe. An alteration of the form of the vessel adapts it to evaporation (fig. 52, *h*) This method of evaporation is admirably suited to the concentration of liquids, that are decomposed, or injured by a higher temperature than that of boiling water, such as medicinal extracts; to the drying of precipitates, &c. In the employment of either of these vessels, it is expedient to surround it with some slow conductor of heat. On a small scale a few folds of woollen cloth are sufficient; and when the vessel is constructed of a large size for practical use, this purpose is served by the brick work in which it is placed.* H. 1. 135.

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* A very convenient apparatus for drying precipitates, &c. is described by Dr Ure. A square ti box, about 18 inches long, 12 broad, and 6 deep, has its bottom hollowed a little by the hammer toward its centre, in which a round hole is cut of 5 or 6 inches diameter. Into this a tin tube, 3 or 4 inche long, is soldered. This tube is made to fit tightly into the mouth of a common tea-kettle, which ha a folding handle. The top of the box has a number of circular holes cut into it, of different diameters into which evaporating capsules are placed. When the kettle, filled with water, and with its nozzl corked, is set on a stove, the vapour playing on the bottoms of the capsules, heats them, to any require temperature; and being itself continually condensed runs back into the kettle. The orifices not i use may be closed with tin lids. In drying precipitates, the tube of the glass funnel, should be corke up, and the funnel be placed, with its filtre, directly into the proper sized opening For drying re cabbage, violet petals, &c. a tin tray is provided, which fits close on the top of the box, within the ri which goes about it. The round orifices are left open when this tray is applied. (*Dict. Chem.* 291.)

145. In breweries and other manufactories, where large quantities of warm and boiling water are consumed, it is frequently heated by thus conveying steam into it, or by suffering steam-pipes to traverse the vessels or by employing double vessels, a plan adopted with particular advantage in the laboratories at Apothecaries Hall. Where a higher temperature than 212° is required it is necessary to employ steam under adequate pressure, and a very ingenious means of producing high pressure steam for this purpose has been contrived by Messrs J. and P. Taylor, and applied by them, upon a very large scale, at Whitbread and Co's brewhouse.

This property taken advantage of in some arts

Steam is transparent.

146. The perfect transparency of steam, and also two other important properties, on which depends its use as a moving power, viz. its elasticity and its condensibility by a reduced temperature, are beautifully shown by a little apparatus contrived by Dr Wollaston. It consists of a glass tube fig. 35, about 6 inches long and ¾ inch bore, as cylindrical as possible, and blown out a little at the lower end. It has a wooden handle, to which is attached a brass clip embracing the tube ; and within is a piston, which, as well as its rod, is perforated, as shown by the dotted lines. This canal may be occasionally opened or closed by a screw at the top : and the piston rod is kept in the axis of the cylinder by being passed through a piece of cork fixed at the top of the tube. When the instrument is used, a little water is put into the bottom; the piston is then introduced with its aperture left open; and the water is heated over a spirit lamp. The common air is thus expelled from the tube, and when this may be supposed to be effected, the aperture in the rod is closed by the screw. On applying heat, steam is produced, which drives the piston upwards. On immersing the bulb in water, or allowing it to cool spontaneously, a vacuum is produced in the tube, and the piston is forced downwards by the weight of the atmosphere. These appearances may be alternately produced by repeatedly heating and cooling the water in the ball of the instrument. In the original steam engine, the vapour was condensed in the cylinder, as it is in the glass tube; but in the engine as improved by Mr Watt, the steam is pumped into a separate vessel, and there condensed ; by which the loss of heat, occasioned by cooling the cylinder every time, is avoided.

Pl. 2,

Reduction of temperature by evaporation.

147. Liquids assume the aëriform state much more rapidly under a diminished pressure, especially if the vapour which is formed be condensed as soon as it is produced, so as to maintain the vacuum ; and the cold produced is very great.

Mr Leslie's method of freezing water.

On this principle depends Mr Leslie's new and ingenious mode of freezing water, in an atmosphere of any common temperature, by producing a rapid evaporation from the surface of the water itself. The water to be congealed is contained in a shallow vessel, which is supported above another vessel, containing strong sulphuric acid, or dry muriate of lime ; or even dried garden mould or parched oatmeal. Any substance, indeed, that powerfully attracts moisture, may be applied to this purpose. The whole is covered by the receiver of an air-pump, which is rapidly exhausted; and as soon as this is effected, crystals of ice begin to shoot in the water, and a considerable quantity of air makes its escape, after which the whole of the water becomes solid. The rarefaction required is to about 100 times; but to support congelation, after it has taken place, 20 or even 10 times are sufficient. The sulphuric acid becomes very warm; and it is remarkable, that, if the vacuum be kept up, the ice itself evaporates. In five or six days, ice of an inch in thickness will entirely disappear. The acid continues to act, till it has absorbed an equal volume of water.

Pl. 1

An elegant manner of making the experiment is to cover the vessel of water (fig. 15, *a*) with a plate of metal or glass, fixed to the end of a sliding wire *b*, which must pass through the neck of the receiver, and be, at the same time, air tight, and capable of being drawn upwards. When the receiver is exhausted, the water will continue fluid, till the cover is removed, when, in less than five minutes, needle-shaped crystals of ice will shoot through it, and the whole will soon become frozen.

In this interesting process, if it were not for the sulphuric acid, an atmosphere of aqueous vapour would fill the receiver; and, pressing on the surface of the water, would prevent the further production of vapour. But the steam, which rises, being condensed the moment it is formed, the evaporation goes on very rapidly, and has no limits but the quantity of the water, and the diminished concentration of the acid.*

Dr Wollaston's Cryophorus.

Pl. 1.

148. It is on the same principle, that the instrument invented by Dr Wollaston, and termed by him the *Cryophorus*, or *Frostbearer*, is founded. It may be formed by taking a glass tube fig. 20, having an internal diameter of about $\frac{1}{8}$th of an inch the tube being bent to a right angle at the distance of half an inch from each ball. One of these balls should be about $\frac{1}{3}$d filled with water, and the other should be as perfect a vacuum as can readily be obtained, the mode of effecting which is well known to those accustomed to blow glass. One of the balls is made to terminate in a capillary tube; and when the water in the other ball has been boiled over a lamp a considerable time, till all the air is expelled, the capillary extremity, through which the steam is still issuing with violence, is held in the flame of the lamp, till the force of the vapour is so far reduced, that the heat of the flame has power to seal it hermetically.

When an instrument of this kind is well prepared, if the empty ball be immersed in a mixture of snow and salt, the water in the other ball, though at the distance of two or three feet, will be frozen solid in the course of a very few minutes. The experiment may be rendered even more striking, if performed according to Dr Marcet's modification of it: the empty ball covered with a little moist flannel, is to be suspended in the manner shown in fig. 17, within a receiver, over a shallow vessel of strong sulphuric acid, and the receiver is then to be exhausted. In both cases the vapour in the empty ball is condensed by the common operation of cold; and the vacuum produced by this condensation gives opportunity for a fresh quantity to arise from the opposite ball, with a proportional reduction of the temperature of its contents. H. 135.

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* The most complete account of this new mode of freezing is to be found in the Supplement, to the Encycl. Brit. art. *Cold*.

Pl. 1.

149. In many natural operations the conversion of water into vapour, and the condensation of vapour in the form of dew and rain, is a process of the utmost importance, and tends considerably to the equalization of temperature over the globe.

Caloric a fluid.

150. Nothing is known of the nature or cause of heat. It has been by some considered as a peculiar fluid, to which the term *Caloric* has been applied; and many phenomena are in favour of the existence of such a fluid. By others, the phenomena above described have been referred to a *vibratory motion* of the particles of matter, varying in velocity with the perceived intensity of the heat. In fluids and gases the particles are conceived to have a motion round their own axes. *Temperature*, therefore, would increase with the velocity of the vibrations; and increase of *capacity* would be produced by the motion being performed in greater space. The loss of temperature, during the change of solids into liquids and gases, would depend upon loss of *vibratory* motion, in consequence of the acquired *rotatory* motion.

A vibratory motion.

Upon the other hypothesis, *temperature* is referred to the *quantity of caloric* present; and the loss of temperature, which happens when bodies change their state, depends upon the chemical combination of the caloric with the solid in the case of liquefaction, and with the liquid in the case of conversion into the aëriform state. B.

Section IV. *Of Light.*

151. The minute investigation of those laws of light which relate to its motion, and effects in producing vision, constitutes a branch of the science of Optics, and therefore belongs to Mechanical Philosophy; it is however requisite that some of them should partially be considered as bearing upon important questions of chemical inquiry.

Vision.

The phenomena of vision are produced either by bodies inherently luminous, such as the sun, the fixed stars, and incandescent substances; or they are referable to the *reflection* of light from the surfaces of bodies.

Light transmitted in right lines.

152. The manner in which the eye is affected by luminous bodies shows that light is transmitted in right lines, and every

right line drawn from a luminous body to the eye is termed a *ray of light*, and as a congeries of rays possesses the same properties as the single ray, the same abstract term is frequently employed to designate the congeries.

Refraction.

153. Newton first discovered that certain bodies exercise on light a peculiar attractive force. When a ray passes obliquely from air into any transparent liquid or solid surface, it undergoes at entrance an angular flexure, which has been called *refraction.* U. 546. The refraction is *towards* the perpendicular when the ray passes into a denser medium, and *from* the perpendicular when it passes into a rarer medium. The medium in which the rays of light are caused to approach nearest to the line perpendicular to its surface, is said to have the greatest refractive density.

Refractive power of inflammable bodies.

154. It was found by Newton, that unctuous, or inflammable bodies occasioned a greater deviation in the luminous rays than their attractive mass, or density gave reason to expect. Hence he conjectured, that both diamond and water contained combustible matter. U. 546.

May be used as a test of their purity.

155. The refractive power of the same inflammable substance bears a proportion to its perfection, insomuch that this property may be used as a test of its purity. Thus Dr Wollaston found that genuine oil of cloves has a refractive power of 1,535, while that of an inferior quality did not exceed 1,498.

Refractive power depends on the chemical nature as well as density.

156. The density of bodies is not the only circumstance that affects their refractive power; it also depends on their chemical nature, and from the refractive power of bodies we may in many cases infer their chemical constitution.

Refractive power of compounds not the mean of that of their constituents.

157. The refractive power of compounds is not the mean deduced from that of their components; which, however, it generally is in mere mixtures.

The following table exhibits the refractive powers of several gaseous and solid bodies; from the experiments of Biot and Arago and from Newton's *Optics*.

(Therm. 32° F. Barom. 30 in.)

Table of the refractive powers of some bodies.

Atmospheric air . . .	1,00000	Hydrogen	6,61436
Carbonic acid	1,00476	Muriatic ether, gaseous	1,71344
Nitrogen	1,03408	Water	1,7225
Muriatic acid gas . . .	1.19625	Gum arabic	1,8826
Oxygen	1,86161	Alcohol	2,2223
Carburetted hydrogen	2,09270	Olive oil	2,7684
Ammonia.	2,16851	Diamond	3,1961

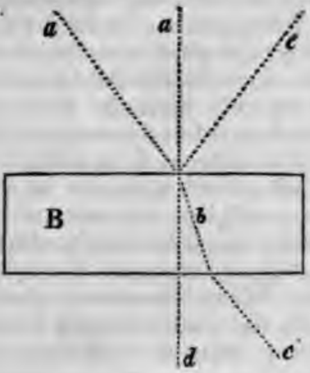
From this it appears that the combustible gases surpass the others in this property, and that hydrogen gas exceeds them all.

Reflected light.

158. When the rays of light arrive at the surfaces of bodies, a part of them, and sometimes nearly the whole, is thrown back, or *reflected*, and the more obliquely the light falls upon the

surface, the greater in general is the reflected portion. In these cases the angle of reflection is always equal to the angle of incidence.

Let *a a* represent pencils of light falling upon the surface of a polished piece of glass B, the perpendicular pencil will pass on in a straight line to *d*. Of the oblique pencil, one portion will enter the glass and suffer refraction towards the perpendicular as at *b*, and re-entering the atmosphere, it will bend from the perpendicular, and re-assume its former direction, as at *c*. Another portion of the oblique pencil will be reflected at an angle equal to that of its incidence, as at *e*.



159. When a ray of light passes through an oblique angular crystalline body, it exhibits peculiar phenomena; one portion is refracted in the ordinary way; another suffers extraordinary refraction, in a plane parallel to the diagonal joining the two obtuse angles of the crystal; so that objects seen through the crystal appear double. Transparent rhomboids of carbonate of lime, or Iceland crystal, exhibit this phenomenon of *double refraction* particularly distinct.

Double refraction.

If a ray of light, which has thus suffered double refraction, be received by another crystal, placed parallel to the first, there will be no new division of the rays; but if it be placed in a transverse direction, that part of the ray which before suffered ordinary refraction will now undergo extraordinary refraction, and reciprocally that which underwent extraordinary refraction now suffers ordinary refraction.

Ordinary and extraordinary refraction.

If the second crystal be turned gradually round in the same plane, when it has made a quarter of a revolution there will be four divisions of the ray, and they will be reduced to two in the half of the revolution; so that the refracting power appears to depend upon some relation of the position of the crystalline particles.

Refracting power seems dependant upon some position of crystalline particles.

160. When light is reflected from bodies, it retains, under many circumstances, its former relations to the refractive power of transparent media; but, in certain cases, at angles differing

for different substances, the reflected rays exhibit peculiar properties, analogous to those which have suffered extraordinary refraction. Thus, if the flame of a taper reflected at an angle of 52° 45′ from the surface of water, be viewed through a piece of double refracting spar, one of the images will vanish every time that the crystal makes a quarter of a revolution.

Angle of incidence equal to the angle of reflection.

161. When a ray of light is made to fall upon a polished glass surface, at an angle of incidence of 35° 25′, the angle of reflection will be equal to that of incidence. Let us suppose another plate of glass so placed that the reflected ray will fall upon it at the same angle of 35° 25′; this second plate may be turned round its axis without varying the angle which it makes with the ray that falls upon it. A very curious circumstance is observed as this second glass is turned round. Suppose the two planes of reflection to be parallel to each other, in that case the ray of light is reflected from the second glass in the same manner as from the first. Let the second glass be now turned round a quadrant of a circle, so as to make the reflecting planes perpendicular to each other: now, the whole of the ray will pass through the second glass, and none of it will be reflected. Turn the second glass round another quadrant of a circle, so as to make the reflecting planes again parallel, and the ray will again be reflected. When the second glass is turned round, three quadrants, the light will be again transmitted, and none of it reflected. Thus, when the reflecting planes are parallel, the light is reflected, but when they are perpendicular the light is transmitted. This experiment proves, that, under certain circumstances, light can penetrate through glass when in one position, but not in another. This curious fact was first observed by Malus, who accounted for it by supposing the particles of light to have assumed a particular position as a needle does when under the influence of a magnet, and hence he called this property of light, its *Polarisation*. (THOMSON's *System*, Vol. i. p. 16.) It has since been studied with laborious diligence by Dr Brewster, and by M. M. Arago and Biot,—*Phil. Trans.* 1813, 1814, 1815, 1816, 1817.—*Annales de Chimie*, tom. 94. *Traité de Physique.*

Curious instance of the transmission and reflection of light.

Polarisation of light.

162. If plates of mica, and certain other crystallized substances, be placed between the glasses employed in the above experiments, so that the reflected rays may traverse them in passing from one surface to the other, it will be found that under certain circumstances, the image of the candle will remain visible; in other words, the light will be *depolarised* in passing through the crystallized medium. Common glass is generally incapable of depolarising the ray, but it acquires the depolarising power when submitted to pressure, or heated, or when it has been heated and very suddenly cooled; the influence of its particles upon those of light becoming then analogous to crystallized bodies.

163. That a sunbeam, in passing through a dense medium,

Prismatic colours.

and especially through a triangular prism of glass, gives rise to a series of brilliant tints similar to those of the rainbow, was known in the earliest ages, but it required the sagacity of Newton to develope the cause of the phenomenon. He proved, that light consists of rays differing from each other in their relative refrangibilities; and, guided by their colour considered their number as seven: red, orange, yellow, green, blue, indigo, and violet. If the prismatic colours, or *spectrum*, be divided into 360 equal parts, the red rays will occupy 45 of these parts, the orange 27, the yellow 48, the green 60, the blue 60, the indigo 40, and the violet 80. Of these rays the red being least refrangible, fall nearest that spot which they would have passed to, had they not been refracted; while the violet rays being most refrangible, are thrown to the greatest distance; the intermediate rays, possess mean degrees of refrangibility.

Newton's theory of colours.

164. These differently coloured rays, are not susceptible of further decomposition, by any number of refractions, but when they are collected into a focus they reproduce white light. Upon these phenomena is founded the Newtonian *theory of colours*, which supposes them to depend upon the absorption of all rays, excepting those of the colour observed. Thus green bodies reflect the green rays and absorb the others. All the rays are reflected by white bodies, and absorbed by those which are black.

Relative temperature of the prismatic rays.

Calorific, and colorific rays separated by the prism.

165. If a solar beam be refracted by a prism, and the coloured image received upon a sheet of paper it will be found, on moving the hand gently through it, that there is an evident increase of temperature towards the red ray. This fact seems to have been first noticed by Dr Hutton (*Dissertation on Light and Heat*, p. 39;) but it is to Dr Herschel (*Phil. Trans.* 1800,) that we are indebted for a full investigation of the subject. If the coloured rays be thrown successively upon delicate thermometers, it will be found, that if the heating power of the violet rays be considered = 16, that of the green rays will be = 26, and of the red = 55. These circumstances suggested the possibility of the heating power of the spectrum extending beyond the red ray; and on applying a thermometer just out of the red ray, and beyond the limits of the visible spectrum, this was found to be the case. A thermometer, in the red ray rose 7° in ten minutes, but just beyond the red ray the rise was = 9°. It is evident, therefore, that, independent of the illuminating rays, there are others which produce increase of temperature, and these from their increase towards the red ray, and from the spot which they principally occupy in the refracted congeries, are possessed of less refrangibility than the visible rays.

Maximum of temperature at the extremity of the red ray.

Dr Herschel's experiments were repeated, with nearly similar results, by Sir H. Englefield, in 1802, and by Mr Berard, in 1813 (Thomson's *Annals*, ii, 163,) who found the maximum of heat to exist just at the extremity of the red ray.

Concentration of these temperatures.

166. That these calorific rays are susceptible of refraction and reflection, is proved by the intense heat produced when the

solar rays are concentrated into a focus by a lens, or by a concave mirror.

Light possesses considerable influence over the chemical energies of bodies.

167. Light possesses considerable influence over the chemical energies of bodies. If a mixture of equal volumes of the gases called chlorine and hydrogen be exposed in a dark room, they slowly combine, and produce muriatic acid gas; but, if exposed to the direct rays of the sun, the combination is very rapid, and often accompanied by an explosion.

Chlorine and carbonic oxide have scarcely any tendency to combine, even at high temperatures, when light is excluded, but exposed to the solar rays they enter into chemical union. Chlorine has little action upon water, unless exposed to light; and, in that case, the water, which consists of oxygen and hydrogen, is decomposed. The hydrogen unites with the chlorine to produce muriatic acid, and the oxygen is evolved in a gaseous form.

Produces chemical changes.

168. These, and numerous other similar cases which might be adduced, show that radiant matter influences the chemical energies of bodies, independent of its heating powers. Scheele (*Experiments on Air and Fire*, p. 78, *&c.*) was the first who entered upon this curious investigation; and many important facts connected with it have been more lately ascertained by Ritter, Wollaston, and Davy. Scheele threw the prismatic spectrum upon a sheet of paper, moistened with a solution of nitrate of silver, a salt quickly decomposed by the agency of light. In the blue and violet rays the silver was soon reduced, producing a blackness upon the paper, but in the red ray scarcely any similar effect was observed. Wollaston and Ritter discovered that these chemical changes were most rapidly effected in the space which bounds the violet ray, and which is out of the visible spectrum.

Division of solar rays by refraction.

169. It has been thus ascertained, that the solar beams are refrangible into three distinct kinds of rays; the *calorific*, or heating rays; the *luminous*, or *colorific*, rays, which produce vision and colour; the *decomposing* rays, or those which have a tendency to interfere with the chemical constitution of bodies.

Not perfectly exhibited in the prismatic spectrum.

In the prismatic spectrum these three sets of rays are imperfectly separated, and arranged according to their respective refrangibilities. The heating rays are the least refrangible, the colorific rays are possessed of more refrangibility, and the decomposing, or, as some have called them, the *deoxidizing rays*, are the most refrangible.

Analogy between the effect of the solar ray and that of electricity.

170. Sir H. Davy has observed, that certain metallic oxides, when exposed to the violet extremity of the prismatic spectrum, undergo a change similar to that which would have been produced by exposure to a current of hydrogen; and that, when exposed to the red rays they acquire a tendency to absorb oxygen. (*Elements of Chemical Philosophy.*) In such general facts, he traces an analogy between the effects of the solar beam, and the agencies of electricity. In the Voltaic circuit, the

maximum of heat is at the positive pole, where the power of combining with oxygen is also given to bodies; the agency of rendering bodies inflammable is exerted at the opposite surface; and similar chemical effects are produced by negative electricity, and by the most refrangible rays; and by positive electricity, and the rays which are least refrangible.

The violet ray of the spectrum capable of exciting magnetic polarity.

171. It has been asserted by Morichini, and the experiment is said to have succeeded in other hands, that the prismatic spectrum is capable of exciting the magnetic influence, and that a needle exposed to the violet rays acquires polarity: this would point out a further analogy between the agencies of light and electricity. B.

Photometer of Leslie.

172. Professor Leslie has constructed an instrument, called a *Photometer*, on the principle that light, in proportion to its absorption produces heat. It is merely a very delicate and small differential thermometer, enclosed in a thin and pellucid glass tube. One of the bulbs is of black glass, which when the instrument is suddenly exposed to light, becoming warmer than the clear bulb, indicates the effect by the depression of the fluid. (LESLIE on *Heat*, P. 424.) A differential thermometer containing the vapour of ether, may also, in certain experiments, be advantageously used as a *Photometric Thermometer*.—(BRANDE, *Phil. Trans.* 1820.)[*]

Perfect vegetation requires the influence of solar rays.

173. In nature the influence of the solar rays is very complex, and the growth, colour, flavour, and even the forms of many vegetables, are much dependent upon them. This is seen in many plants which are protected from the sun's rays: celery and endive are thus cultivated with the view of rendering them palatable[†]; and plants which are made to grow in a room imperfectly illuminated, always bend towards the apertures by which the sun's rays enter. The changes too which vegetables effect upon the circumambient atmosphere are influenced by the same cause.

In the animal creation, brilliancy of colour and gaudy plumage belong to the tropical climates; more sombrous tints distinguish the polar inhabitants; and dull colours characterize nocturnal animals, and those who chiefly abide below the surface.

Phosphorescent bodies.

174. There are many substances which, when heated to a certain point, become luminous without undergoing combustion, and such bodies are said to be *phosphorescent*. The temperatures which they require for this purpose are various; it generally commences at about 400°, and may be said to terminate at the lowest visible redness. Some varieties of phosphate of lime, of fluor spar, of bituminous carbonate of lime, of marble, and sand, and certain salts, are the most remarkable bodies of this description. (WEDGWOOD, *Phil. Trans.* Vol. 82.) Their luminous property may be best exhibited by scattering them in coarse powder upon an iron plate heated nearly to redness.

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[*] A new photometer has been described by Mr Ritchie. See *Quarterly Journal*, Vol. 19; p. 299.

[†] The process is termed *etiolution* or blanching.

Oil, wax, spermaceti, and butter, when nearly boiling, are also luminous.

Solar Phosphori.

175. Another class of phosphorescent bodies have been termed *solar phosphori*, from becoming luminous when removed into a dark room after having been exposed to the sunshine. Of this description are Canton's, Baldwin's, and the Bolognian phosphorus.

Canton's compound.

Canton's phosphorus is prepared thus:—Calcine oyster-shells in the open fire for half an hour, then select the whitest and largest pieces and mix them with one third their weight of flowers of sulphur, pack the mixture closely into a covered crucible, and heat it to redness for an hour. When the whole has cooled, select the whitest pieces for use.—*Phil. Trans.* Vol. 58.

Baldwin's and the Bolognian phosphorus.

Baldwin's phosphorus is prepared by heating nitrate of lime to a dull red heat, so as to form it into a compact mass: and the Bolognian phosphorus, discovered by Vincenzio Cascariolo, a shoemaker of Bologna, is made by reducing compact sulphate of baryta to a fine powder, which is formed into cakes with mucilage, and these are heated to redness.—AIKIN's *Dictionary*, Art. *Phosphori.*

Wilson's experiments.

176. Mr B. Wilson has also made a variety of curious experiments on solar phosphori; and, he has discovered the simplest and most effectual of these bodies, which may be obtained by closely observing the following directions:—Take the most flaming coals off a brisk fire, and throw in some thick oyster-shells; then replace the coals, and calcine them for an hour; remove them carefully, and, when cold, it will be found that after exposing them for a few minutes to the light, they will glow in the dark, with most of the prismatic colours.—WILSON *on Phosphori*, p. 20.

Spontaneous Phosphori.

177. A third set of bodies, belonging to this class, are those which are *spontaneously phosphorescent*. Such are especially, the flesh of salt-water fish just before it putrefies, and decayed wood. The *glow-worm*, and the *lantern-fly*, are also luminous when alive; and the *hundred legged worm*, and some others, shine brilliantly when irritated.

It appears from the experiments of Canton and of Dr Hulme, (*Phil. Trans.* Vols. lix. xc. and xci.) that sea-fish become luminous in about twelve hours after death, that it increases till putrefaction is evident, and that it then decreases. Immersion in sea-water does not affect this luminous matter, on the contrary, the brine is itself rendered luminous; but it is extinguished by pure water, and by a variety of substances which act chemically upon the animal matter.

Light from percussion of friction.

178. Percussion and friction are often attended by the evolution of light as when flint pebbles, pieces of sugar, and other substances, are struck or rubbed together.

Gases incapable of becoming luminous.

179. From experiments in which air has been intensely heated, it has been concluded that gaseous matter is incapable of becoming luminous; for, though the temperature of air be such

The intensity of the heat of flames which are but little
s, as of hydrogen gas, spirit of wine, *&c.*, may be shown
ducing into them some fine platinum wire, which is in-
rendered white hot in those parts where the combustion
perfect. It is even intensely ignited in the current of **Height and temperature of flame.**
e the flame, as may be shown by holding a piece of
a wire over the chimney of an Argand lamp fed with
wine; the high temperature of this current is also ex-
by the common expedient of lighting paper by holding
heated air which rushes out of a common lamp-glass.
The high temperature of flame is further proved by cer-
s of combustion without flame. Thus, if a heated wire
ium be introduced into any inflammable or explosive
, it will become *ignited*, and continue so till the gas is
ed; but *inflammation* will, in most cases, only take
hen the wire becomes white hot. This experiment is
ade by pouring a small quantity of ether into the bottom **Exp.**
r-glass, and holding, a piece of heated platinum wire a
ove its surface; the wire becomes red hot, but does not
the vapour of the ether till it acquires an intense white

ame fact is exhibited by putting a small coil of platinum
nd the wick of a spirit lamp, fig. 34, which, when heated, **Pl. 2.**
s red hot, and continues so, as long as the vapour of the **Platinum wire lamp.**
supplied, the heat never becoming sufficiently intense
ice its inflammation.
Such being the nature of flame, it is obvious, that if we
y any means, we must at the same time *extinguish* it.
y be effected by causing it to pass through fine wire
which is an excellent conductor and radiator of heat, and
ently possessed of great cooling power. If a piece of **Exp.**
ss or iron wire-gauze be brought down upon the flame

tissue that will interrupt the flame of less inflammable substances, or those that produce little heat in combustion; so that different flames will pass through at different degrees of temperature.

Davy's safety lamp.

184. The discovery of these facts, respecting the nature and properties of flame, led Sir H. Davy to apply them to the construction of the *Miners' safety lamp*, which will be explained under the article *Carburetted hydrogen gas.*

On the properties of phosphorescence and incandescence.

185. The phenomena exhibited by phosphorescent and incandescent bodies, and in the process of combustion, have sometimes been explained upon the idea that the light and heat evolved, were previously in combination with the substances, and that they are afterwards merely emitted, in consequence of decomposition; and that the solar phosphori absorb light and again give it out unchanged. But it appears more probable that any particles violently repelled into space may become *radiant matter*, than that it should consist of a *specific* substance: thus mechanical action, and chemical changes, may each tend to the emission of radiant matter; and incandescence will result when the vibrations which heat occasions among the particles of bodies are of such violence as to cause their repulsion into space. (B.) (See DAVY's *Elements of Chemical Philosophy*, 1. 213, &c.)

SECTION V. *Electricity.*

Electrical excitement.

186. IF a piece of sealing-wax and of dry warm flannel be rubbed against each other, they both become capable of attracting and repelling light bodies. A dry and warm sheet of writing-paper, rubbed with India rubber, or a tube of glass rubbed upon silk, exhibit the same phenomena. In these cases the bodies are said to be *electrically excited;* and when in a dark room, they always appear luminous.

Repulsion and attraction.

187. If two pith-balls be electrified by touching them with the sealing-wax or with the flannel, they repel each other; but if one pith-ball be electrified by the wax, and the other by the flannel, they attract each other. The same applies to the glass and silk: it shows a difference in the electricities of the different bodies, and the experiment leads to the conclusion, that *bodies similarly electrified repel each other, but that when dissimilarly electrified they attract each other.*

Repulsion.

The term *electrical repulsion* is here used merely to denote the appearance of the phenomenon, the separation being probably referable to the new attractive power which they acquire, when electrified, for the air and other surrounding bodies.

If one ball be electrified by sealing-wax rubbed by flannel, and another by silk rubbed with glass, those balls will repel each other; which proves that the electricity of the silk is the same as that of the sealing-wax. But if one ball be electrified by the sealing-wax and the other by the glass, they then attract each other, showing that they are oppositely electrified.

Franklin's theory.

188. The terms *vitreous* and *resinous* electricity were applied to these two phenomena; but Franklin, observing that the same electricity was not inherent in the same body, but that glass sometimes exhibited the same phenomena as wax, and *vice versâ*, adopted another term, and, instead of regarding the phenomena as dependant upon two electric fluids, referred them to the presence of one fluid, in excess in some cases, and in deficiency in others. To represent these states he used the terms *plus* and *minus*, *positive* and *negative*. When glass is rubbed with silk, a portion of electricity leaves the silk and enters the glass; it becomes *positive*, therefore, and the silk *negative*; but when sealing-wax is rubbed with flannel, the wax loses and the flannel gains; the former, therefore, is negative, and the latter positive. All bodies in nature are thus regarded as containing the electric fluid, and when its equilibrium is disturbed, they exhibit the phenomena just described.

189. The substances enumerated in the following table become positively electrified when rubbed with those which follow them in the list, but with those which precede them they become negatively electrical.—Biot, *Traité de Physique*, tom. ii., p. 220.

Cat's skin.
Polished glass.
Woollen cloth.
Feathers.
Paper.
Silk.
Gum lac.
Rough glass.

Electrometer.

190. Very delicate pith-balls, or strips of gold leaf, are usually employed in ascertaining the presence of electricity; and, by the way in which their divergence is affected by glass or sealing-wax, the kind or state of electricity is judged of. When properly suspended or mounted for delicate experiments, they form an *electrometer* or *electroscope*. For this purpose the slips of gold leaf are suspended by a brass cap and wire in a glass cylinder; they hang in contact when unelectrified; but when electrified they diverge.

Method of determining the kind of electricity.

191. The kind of electricity by which the gold leaves are diverged may be judged of by approaching the cap of the instrument with a stick of excited sealing-wax; if it be *negative* the divergence will increase; if *positive*, the leaves will collapse, upon the principle of the mutual annihilation of the opposite electricities, or that bodies similarly electrified repel each other, but that when dissimilarly electrified they become mutually attractive. (187.)

Conductors & nonconductors.

192. Some bodies suffer electricity to pass through their substance, and are called *conductors*. Others only receive it upon the spot touched, and are called *nonconductors*. The former do not, in general become electric by friction, and are called *nonelectrics*: the latter, on the contrary, are *electrics*, or ac-

Pl. 2.

The *electrophorus*, fig. 41, consists of two metallic plates, *a a*, with an intervening plate of resinous matter, *b*, for which equal parts of shellac, resin, and Venice turpentine, are generally used, the mixture being carefully melted in a pipkin, and poured, whilst liquid, into a wooden or metal hoop, of a proper size, placed upon a polished surface of glass or marble, from which it easily separates when cold; it should be about half an inch thick, and the smooth surface being uppermost the lower side should be covered with tin foil, or attached to any other metallic plate; a polished brass plate, with a glass handle *c* attached to it, is then placed upon the upper surface of the resinous plate, and of rather smaller diameter. The resin is then to be excited with a piece of dry fur, and the instrument will be found to exhibit the following phenomena:

Mode of using it.

Upon raising the brass plate by its insulating handle, it will be found very feebly electrical; replace it, touch it with the finger and again lift it off by its handle, and it will give a spark of positive electricity. This process may very often be repeated without fresh excitation, which circumstance, as well as the nature of the electrical charge, shows that the electricity of the moveable brass plate is not directly derived from the resin, but that it depends upon induction.

The electrophorus used as an electric machine.

The electrophorus may often be used for the same purpose as the electrical machine, and in the laboratory it furnishes a very convenient substitute for that more expensive piece of apparatus.

Quantity and intensity of electric power.

202. Electritians generally employ the term *quantity* to indicate the absolute quantity of electric power in any body, and the term *intensity* to signify its power of passing through a certain stratum of air or other ill-conducting medium.

Illustration.

If we suppose a charged Leyden phial to furnish a spark, when discharged, of one inch in length, we should find that another uncharged Leyden phial, the inner and outer coating of which were communicated with those of the former, would upon the same quantity of electricity being thrown in, reduce the length of the spark to half an inch; here, the *quantity* of electricity remaining the same, its *intensity* is diminished by one-half, by its distribution over the larger surface.

Power of the Leyden jar in proportion to its surface.

203. The power of the Leyden jar is proportioned to its surface, but a very large jar is inconvenient and difficult to procure; the same end is attained by arranging several jars, so that by a communication existing between all their interior coatings, their exterior being also united, they may be charged and discharged as one jar. Such a combination is called an electrical *Battery*, and is useful for exhibiting the effect of accumulated electricity.

Electrical Battery.

Its discharge attended with report can prove fatal to animal life.

The discharge of the battery is attended by a considerable report, and if it be passed through small animals it instantly kills them; if through fine metallic wires, they are ignited, melted, and burned; and gunpowder, cotton sprinkled with powdered resin, and a variety of other combustibles, may be inflamed by the same means.

Produces combustion, &c.

Other sources of electricity.

204. There are many other sources of electricity than those just noticed. When glass is rubbed by mercury, it becomes electrified, and this is the cause of the luminous appearance observed when a barometer is agitated in a dark room, in which case flashes of light are seen to traverse the empty part of the tube. Even the friction of air upon glass is attended by electrical excitation: for Mr Wilson found that by blowing upon a dry plate of glass with a pair of bellows, it acquired positive electricity. Whenever bodies change their forms, their electrical states are also altered. Thus the conversion of water into vapour, and the congelation of melted resins and sulphur, are processes in which electricity is also rendered sensible.

205. When an insulated plate of zinc is brought into contact with one of copper or silver, it is found, after removal, to be positively electrical, and the silver or copper is left in the opposite state.

Of two metals properly connected the most oxidizable one is always positive.

The most oxidizable metal is always positive, in relation to the least oxidizable metal, which is negative, and the more opposite the metals in these respects, the greater the electrical excitation; and if the metals be placed in the following order, each will become positive by the contact of that which precedes it, and negative by the contact of that which follows it; and the greatest effect will result from the contact of the most distant metals.

Metallic arrangement for electric excitation.

Platinum.
Gold.
Silver.
Mercury.
Copper.
Iron.
Tin.
Lead.
Zinc.

Electricity conducted by nerves.

If the nerve of a recently killed frog be attached to a silver probe, and a piece of zinc be brought into the contact of the muscular parts of the animal, violent convulsions are produced every time the metals thus connected are made to touch each other; exactly the same effect is produced by an electric spark, or the discharge of a very small Leyden phial.

If a piece of zinc be placed upon the tongue, and a piece of silver under it, a peculiar sensation will be perceived every time the two metals are made to touch.

Chemical action accompanying that of electricity.

206. In these cases the chemical properties of the metals are observed to be affected. If a silver and a zinc wire be put into a wine glass full of dilute sulphuric acid, the zinc wire only will evolve gas; but upon bringing the two wires in contact with each other, the silver will also copiously produce air bubbles.

Pl. 2.

Electric column.

207. If a number of alternations be made of copper or silver leaf, zinc leaf, and thin paper, fig. 38, the electricity excited by

the contact of the metals will be rendered evident to the common electrometer.

208. If the same arrangement be made with the paper moistened with brine, or a weak acid, it will be found on bringing a wire communicating with the last copper plate into contact with the first zinc plate, that a spark is perceptible, and also a slight shock, provided the number of alternations be sufficiently numerous. This is the VOLTAIC apparatus.

Volta's.

Another mode of constructing the apparatus.

209. Several modes of constructing this apparatus have been adopted, with a view to render it more convenient or active. Sometimes double plates of copper and zinc soldered together, are cemented into wooden troughs in regular order, fig. 48, the intervening cells being filled with water, or saline or acid solutions.

Coronne de tasse another variety of form.

210. Another form consists in arranging a row of glasses, containing dilute sulphuric acid, in each of which is placed a wire or plate of silver or copper, and one of zinc, not touching each other, but so connected by metallic wires, that the zinc of the first cup may communicate with the copper of the second; the zinc of the second with the copper of the third, and so on throughout the series, as represented in fig. 44.

By dipping the fingers into the extreme cups 1 and 4 a shock will be felt; and on making a communication between them by a wire, it will be found that the copper plates instantly acquire the power of decomposing the dilute sulphuric acid, and that the chemical action of the zinc is much augmented. One advantage of this arrangement over the former (209) is, that both surfaces of the metal are exposed; whereas in the other, by soldering the plates together, its action is diminished.

Pl. 3.

The most approved construction.

211. In fig. 55, the trough A is made of earthenware, with partitions of the same material, and the metallic plates are attached to a bar of wood, so that they can be immersed and removed at one operation. The troughs are filled with dilute acid, and by uniting them in regular order, the apparatus may be enlarged to any extent. It is thus that the great apparatus of the Royal Institution is constructed.

212. When from 500 to 1000 double plates are thus arranged and rendered active by immersion into a liquid consisting of about sixty parts of water with one of nitric and one of sulphuric acid, very brilliant effects are produced when the opposite poles are properly united by conductors. Thus, if a piece of charcoal united with the negative wire be made to touch another piece united with the positive wire, a bright spark and intense ignition ensue, and by slowly withdrawing the points from each other a constant current of electricity takes place through the heated air, producing a magnificent arc of intense light.

Galvanic combustion of charcoal.

Combustion and fusion of metals.

213. When the metals and other inflammable bodies are placed in this arc of fire they burn with great brilliancy, and those which are most difficult of fusion give evidence of the intensity of the heat by instantly melting; and some earthy and other bodies, infusible by ordinary methods, are liquefied by

ed, of Copenhagen.

5. On immersing the wires from the extremes of this ap-
us into water, it is found that the fluid suffers decomposi- **Decomposition of water.**
and that oxygen gas is liberated at the positive wire or
and hydrogen gas at the negative pole.

6. One of the first discoveries of the chemical agency of
ile was its power of decomposing water. Two pieces of **Exp.**
ietallic wires are thrust through separate corks, which are
into the open ends of a glass tube in such a way, that the
mities of the wires, when the corks are in their places, may
e in contact, but may be at the distance from each other
out a quarter of an inch (see fig. 46, *a*). If the parts of the **Pl. 2.**
which project from without the tube, be made to commu-
, the one with the zinc or positive end, and the other with
pper or negative end, of a galvanic battery, a remarkable
rance takes place. The wire, connected with the zinc or
ve end of the pile or trough, where it is in contact with
ater. if of an oxidable metal, is rapidly oxidized; while,
the negative wire a stream of small bubbles of gas arises.
f the wires employed be of a metal which is not suscepti-
oxidation, such as gold or platina, gas is then extricated
both wires, and, by a simple contrivance, may be sepa-
collected. The apparatus for this purpose is shown by
1, where the wires *p* and *n*, instead of being introduced **Pl. 2.**
a straight tube, are inclosed in a syphon, and terminate
they reach the end, in which a small hole is to be ground.
a stream of galvanic electricity is made to act upon water
confined, oxygen gas is found, at the close of the experi-
in the leg connected with the positive end of the battery,
ydrogen gas in that connected with the negative end; and
proportions, which, by their union, compose water. At
rly period of the inquiry, it was found, however, by Mr
kshank, that the water surrounding the positive wire be-
impregnated with a little acid; and that around the nega-

Method of obtaining oxygen and hydrogen separately.

Pl. 2.

Exp.

The fact is of peculiar importance from its resemblance to other more recent ones, which have led that distinguished philosopher to the discovery of the general laws of electro-chemical action. Two glass tubes, (p and n, fig. 45), about one-third of an inch in diameter and four inches long, having each a piece of gold wire sealed hermetically into one end and the other end open, were filled with distilled water, and placed, inverted in separate glasses, filled, also, with that fluid. The two glasses, a and b, were made to communicate, either by dipping the fingers of the right hand into one glass, and those of the left into the other, or by interposing fresh animal muscle, or a living vegetable, or even moistened thread, as shown at c. The gold wires, projecting from the sealed ends of these tubes, were then connected, the one with the positive, the other with the negative end of the trough. Gas was immediately evolved from both wires. At the close of the experiment, in the tube p, oxygen gas was found; in the negative tube n, hydrogen. The proportions by measure were, as nearly as possible, those which result from the decomposition of water, *viz.* two of hydrogen to one of oxygen gas. Now if these gases arose, as they necessarily must, from the decomposition of the same portion of water, that portion of water must have been contained either in the tube p or in the tube n. In the former case, the hydrogen gas, found after the process in n, must have passed invisibly from p to n, through the intermediate substance c. Or, if the water was decomposed in n, then the reverse process must have happened with respect to the oxygen; and it must have been transmitted, in a like imperceptible manner, from n to p. Facts of this kind, evincing the transference of the elements of a combination, to a considerable distance, through intervening substances, and in a form that escapes the cognizance of our senses, however astonishing, it will appear from the sequel, are sufficiently numerous and well established. It appears, also, from the experiments of Mr Porrett, that water may be forced, contrary to its gravity, through the compact substance of a bladder, from the positive to the negative wire of a galvanic battery, composed of plates only 1¼ inch square. H. 1. 177.

Combustible constituents, join in the negative pole.

Explanation.

Supporters of combustion are attracted to the positive pole.

218. All other substances are decomposed with similar phenomena, the inflammable element being disengaged at the negatively electrical surface; hence it would appear, upon the principle of similarly electrified bodies repelling each other, and dissimilarly electrified bodies attracting each other, (187) that the inherent or natural electrical state of the inflammable substances is *positive*, for they are attracted by the negative or oppositely electrified pole; while the bodies, sometimes called supporters of combustion, or acidifying principles, are attracted by the positive pole, and, therefore, may be considered as possessed of the *negative* power.

Chemical union destroyed by galvanism.

219. When bodies are thus under the influence of electrical decomposition, their usual chemical energies are suspended,

nd some very curious phenomena are observed, which may be llustrated by the following experiments.

Pl. 2. Exp.

Fill the glass tubes A A, fig. 40, which are closed at top and pen at bottom, with infusion of violets, or red cabbage, and vert them in the basins B B, containing a solution of Glauber's lt, and connected by the glass tube C, also containing the blue fusion. P and N are platinum wires, which pass into the tubes early to the bottom, and which are to be connected with e positive and negative extremities of the Voltaic apparatus. t will be found that oxygen is evolved at the wire P, and hyrogen at N, derived from the decomposition of the water. The lauber's salt, which consists of sulphuric acid and soda, will lso be decomposed; and the blue liquor will be rendered red n the positive vessel, by the accumulation of sulphuric acid, nd green in the negative, by the soda, while the acid and alcali vill each traverse the tube C without uniting, in consequence f being under the influence of electrical attraction.

220. The most difficultly decomposable compounds may be hus resolved into their component parts by the electrical gency; by a weak power the proximate elements are separated, nd by a stronger power these are resolved into their ultimate onstituents.

Different compounds require different arrangements.

221. Different chemical compounds require, for the disunion f their elements galvanic arrangements of various powers, and ntensities. The decomposition of water is easily effected by a eries of fifty pairs of plates, each, one or two inches square. But for some other decompositions, instruments of greater ower are required.

Davy's experiments.

222. The apparatus employed by Sir H. Davy was extremely imple. Where liquid substances were to be operated upon, e employed occasionally agate and gold cups, fig. 56, each of which was capable of holding about 60 grains of water. These were connected by fibres of amianthus, and into each was inerted a platina wire. The wires were connected with the two xtremities of a powerful galvanic series.

Pl. 2.

223. Solid bodies were submitted to the galvanic influence, ither by immersing small pieces of them in gold cones, fig. 57; r, at other times, by making the cups themselves of the substance intended to be decomposed. Or if it was desirable to preserve them from contact with water, they were laid on a mall insulated dish of platina, with the inferior surface of which, immediately under the substance used, a wire from one end of the battery was made to communicate by another wire, with the opposite extremity of the apparatus.

Pl. 2.

224. When the gold cones were both filled with a solution of ulphate of potash (a salt composed of potash and sulphuric cid,) after exposure, during a sufficient time, to a powerful galvanic arrangement, pure potash was found in the negative cup, and sulphuric acid in the positive. The decomposition was quite complete, no acid being found in one cone, and no lkali in the other.

The experiment was repeated with several other neutral salts, and with the invariable result, that the acid collected in the positive cone, and the alkali in the negative one.

Decomposition of insoluble bodies, &c.

225. Salts which are either insoluble, or very sparingly soluble in water, had their elements disunited in the following manner. Cups were constructed of them, which were filled with water, and connected by platina wires with the opposite ends of a galvanic battery, the vessels themselves communicating as before, by means of moistened amianthus. At the conclusion of the experiment sulphuric acid (when the cups were made of sulphate of lime) was found in the positive cup, and lime water in the negative one. Sulphate of strontites, fluate of lime, and sulphate of baryta, were decomposed, though less easily, by the same expedient. In all these cases the acid element was found at the positive side, and the earthy one at the negative side, of the arrangement.

Transfer of the elements.

226. These facts evidently point out a transference of the elements of combination from one electrified vessel, or surface, to another differently electrified. The principle may be made much more apparent by a little variation of the experiment.

Pl. 2.

Thus, if solution of sulphate of potash be electrified in the positive cone *p*, fig. 57, water alone being contained in *n*, after a sufficient continuance of the electrical action, *p* will be found to contain diluted sulphuric acid, and the potash will be discovered in the water of *n*. The alkali must necessarily, therefore, have passed, in an imperceptibte form, along the connecting amianthus, from the vessel *p* to the vessel *n*. Reversing the experiment, and filling *n* with solution of sulphate of potash, the alkali remains in this cone; and the acid is transferred to the opposite side *p*. In one experiment, in which nitrate of silver was placed in the positive cup, and pure water in the negative one, the whole of the connecting amianthus was covered with revived silver.

Pl. 2,

Exp.

227. In the farther prosecution of the inquiry, Sir H. Davy succeeded in discovering a still more extraordinary series of facts. When an intermediate vessel (*i*, fig. 47) was placed between the positive and negative cups *p* and *n*, and was connected with both of them by moistened amianthus, it was found, that acids may actually be made to pass from *n* to *p*, through the intermediate solution in *i*, without combining with it. Thus solution of sulphate of potash being put into the negative cup *n*, solution of pure ammonia into *i*, and pure water into *p*; in half an hour, sulphuric acid was found in the water of the positive cup, to have reached which it must have been transferred from *n* through the intermediate solution of ammonia. Muriatic acid, also, from muriate of soda, and nitric acid from nitrate of potash, were transferred from the negative to the positive side through an interposed solution of alkali. And contrariwise, alkalies and metallic oxides were transmitted from the positive to the negative side, through intervening solutions of acids.

It is necessary, however, that the solution, contained in the intermediate vessel *i*, should not be capable of forming an insoluble compound with the substance intended to be transmitted through it. Thus sulphuric acid, in its passage, from sulphate of potash in the negative cup, through the vessel *i* containing a solution of pure barytes, is detained by the barytes, and falls down in the state of an insoluble compound with that earth.

228. Bodies, the composition of which is considerably more complicated, are, also, decomposed by galvanic electricity. Thus, from certain minerals, containing acid and alkaline matter in only very minute proportion, these ingredients are separately developed. Basalt, for example, (a kind of stone, which, in 100 grains, contains only $3\frac{1}{2}$ grains of soda and half a grain of muriatic acid,) gave, at the end of ten hours, evident traces of alkali round the negative, and of acid round the positive wire. A slip of glass, also, negatively electrified in one of the gold cones, had soda detached from it, and sustained a loss of weight.

The alkali and acid derived from the impurities of the water.

229. It may now be understood, why, by the agency of galvanism on water, alkali appears at the negative and acid at the positive wire. The fact was, for some time, not a little perplexing to Sir H. Davy; till, at length, he ascertained, that all water, however carefully distilled, contains neutral salts in a state of solution. From these impurities, the alkaline and acid elements are separated, agreeably to a law which has already been explained. In the same way, also, the muriatic acid and alkali are accounted for, which some chemists have obtained by galvanizing what was before considered as pure water; a fact which has been urged in proof of the synthetical production of both those bodies. Absolutely pure water, it has been demonstrated by Sir H. Davy, yields nothing but hydrogen and oxygen gases.

Similar effects of ordinary electricity.

230. All the effects of galvanic arrangements, in producing chemical decompositions, it has been found, may be obtained by ordinary electricity. Its adaptation to this purpose was first successfully attempted by Dr Wollaston.* The apparatus, which he employed, was similar to that already represented, fig. 46, *a*, excepting that the wires instead of being exposed to the fluid, contained in the tube, throughout their whole length, were covered with wax, and the points only were laid bare. Or (what was found to answer still better) the wires were inclosed in capillary tubes, which were sealed at their extremities, and then ground away, till the points alone were exposed. The conducting wires, thus arranged, were then introduced into a tube, or other vessel containing the liquid to be operated on, and were connected, the one with the positive, the other with the negative, conductor of an electrical machine, disposed for positive and negative electricity.† When solution

Pl. 2.

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* Philos. Trans. 1801.

† See Cuthbertson's Practical Electricity.

of sulphate of copper was thus electrized, the metal was revived round the negative pole. On reversing the apparatus, the copper was re-dissolved, and appeared again at the other wire, now rendered negative.

When gold wires, from $\frac{1}{700}$ to $\frac{1}{1500}$ of an inch in diameter, thus enclosed, were made to transmit electricity, a succession of sparks afforded a current of gas from water. When a solution of gold in nitro-muriatic acid was passed through the capillary tube; the tube then heated to drive off the acid; and afterwards melted and drawn out, it was found that the mere current of electricity, without sparks, evolved gas from water.

Sir H. Davy has since proved, that, by a similar apparatus, solution of sulphate of potash is decomposed, potash appearing at the negative, and sulphuric acid, at the positive pole.* H. 1. 178.

Davy's idea of the connection between chemical attraction and galvanism.

231. All bodies which exert powerful chemical agencies upon each other when freedom of motion is given to their particles, render each other oppositely electrical when acting as masses. Hence Sir H. Davy, the great and successful investigator of this branch of chemical philosophy, has supposed that electrical and chemical phenomena, though in themselves quite distinct, may be dependent upon one and the same power, acting in the former case upon masses of matter, in the other upon its particles.

Circumstances promoting the power of the Voltaic apparatus.

232. The power of the Voltaic apparatus to communicate divergence to the electrometer, is most observed when it is well insulated and filled with pure water; but its power of producing ignition and of giving shocks, and of producing the other effects observed when its poles are connected, are much augmented by the interposition of dilute acids, which act chemically upon one of the plates: here, the insulation is interfered with by the production of vapour, but the quantity of electricity is much increased, a circumstance which may, perhaps, be referred to the increase of the positive energy of the most oxidable metal by the contact of the acid. In experiments made with the great battery of the Royal Institution, it has been found that 120 plates rendered active by a mixture of one part of nitric acid and three of water, produced effects equal to 480 plates rendered active by one part of nitric acid and fifteen of water.

Arrangement for intensity for quantity.

233. In the Voltaic pile, the *intensity* of the electricity increases with the number of alternations, but the *quantity* is increased by extending the surface of the plates. Thus, if a battery, composed of thirty pairs of plates two inches square, be compared with another battery of thirty pairs of twelve inches square, charged in the same way, no difference will be perceived in their effects upon bad or imperfect conductors; their powers of decomposing water and of giving shocks will be similar; but upon good conductors the effects of the large plates will be considerably greater than those of the small: they will

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* Philos. Trans. 1806.

ignite and fuse large quantities of platinum wire, and produce a very brilliant spark between the charcoal points. The following experiment will illustrate the different effects of quantity and intensity in the Voltaic apparatus.

Experimental illustration.

Immerse the platinum wires connected with the extremity of a charged battery composed of twelve-inch plates into water, and it will be found that the evolution of gas is nearly the same as that occasioned by a similar number of two-inch plates. Apply the moistened fingers to the wires, and the shock will be the same as if there were no connexion by the water. While the circuit exists through the human body and the water, let a wire attached to a thin slip of charcoal be made to connect the poles of the battery, and the charcoal will become vividly ignited. The water and the animal substance discharge the electricity of a surface probably not superior to their own surface of contact with the metals; the wires discharge all the residual electricity of the plates; and if a similar experiment be made on plates of an inch square, there will scarcely be any sensation when the hands are made to connect the ends of the battery, a circuit being previously made through water; and no spark, when charcoal is made the medium of connexion, imperfect conductors having been previously applied.

Mr Children's battery.

These relative effects of quantity and intensity were admirably illustrated by the experiments instituted by Mr Children, who constructed a battery, the plates of which were two feet eight inches wide, and six feet high. They were fastened to a beam suspended by counterpoises from the ceiling of his laboratory, so as to be easily immersed into or withdrawn from the cells of the acid. The effects upon metallic wires and perfect conductors were extremely intense; but upon imperfect conductors, such as the human body, and water, they were feeble. —*Philos. Trans.* 1815, p. 363.

Pl. 3.

Dr Hare's improvement.

234. One of the most convenient methods of constructing a battery of extensive surface has been contrived by Dr Hare, fig. 59, who has given the instrument the name of Calorimotor. A *a*, represent two cubical vessels, twenty inches square, inside. *b b b b*, a frame of wood containing 20 sheets of copper, and 20 sheets of zinc, alternating with each other, and about half an inch apart. T T *t t*, masses of tin cast over the protruding edges of the sheets which are to communicate with each other. Fig. 60, represents the mode in which the junction between the various sheets and tin masses is effected. Between the letters *z z*, the zinc only is in contact with the tin masses. Between *c c* the copper alone touches. It may be observed, that, at the back of the frame, ten sheets of copper between *c c*, and ten sheets of zinc between *z z*, are made to communicate, by a common mass of tin extending the whole length of the frame, between T T: but in front, as in fig. 59, there is an interstice between the mass of tin, connecting the ten copper sheets, and that connecting the ten zinc sheets. The screw forceps,

appertaining to each of the tin masses, may be seen on either side of the interstice: and likewise a wire for igniton held between them. The application of the rope, pulley, and weights is obvious. The swivel at S permits the frame to be swung round and lowered into water in the vessel *a*, to wash off the acid, which, after immersion in the other vessel, might continue to act on the sheets, encrusting them with oxide. Between *p p*, there is a wooden partition, which is not necessary, though it may be beneficial.

When the copper and zinc surfaces are united by an intervening wire, and the instrument immersed in the acid liquor in the vessel beneath, the wire becomes intensely ignited, and when hydrogen is liberated in sufficient quantity it usually takes fire producing a very beautiful corruscating flame upon the surface of the liquid. (See *American Jour. of Science*, Vol. 1. 413.)

Metallic fusion.

235 When the extremes of a battery composed of large plates are united by wires of different metals, it is found that some are more easily ignited than others, a circumstance which has been referred to their conducting powers: thus, platinum is more easily ignited than silver, and silver, than zinc. If the ignition be supposed to result from resistance to the passage of electricity, we should say that the zinc conducted better than silver, and the silver than platinum.

Wollaston's improvement.

Pl. 3.

236. An important improvement has been suggested in the construction of the Voltaic apparatus by Dr Wollaston, (*Annals of Philosophy*, Sept. 1815,) by which great increase of *quantity* is obtained without inconvenient augmentation of the size of the plates: it consists in extending the copper plate, so as to oppose it to every surface of the zinc, as seen in fig. 61. A is the rod of wood to which the plates are screwed; BB the zinc plates connected as usual with the copper plates CC, which are doubled over the zinc plates, and opposed to them upon all sides, contact of the surfaces being prevented by pieces of wood or cork placed at DD.

The most economical & useful form.

With a single pair of plates of very small dimensions constructed upon this principle, Dr Wollaston succeeded in fusing and igniting a fine platinum wire. From the experience which I have had of this construction, I am inclined to consider it the most economical and useful form of the Voltaic apparatus; certainly, at least, it is so for all those researches in which there is an occasional demand for quantity as well as intensity of electricity. (B.)

Pl. 3.

Dr Hare's Deflagrator.

237. Fig. 62, represents the improved form of the Voltaic apparatus of Dr Hare, which he has called a Deflagrator. It consists of four troughs A. A. B. B. each 10 feet long. Each two of the troughs are joined lengthwise, edge to edge, so that when the sides of the two B B are vertical, those of the others A A are horizontal. The troughs are supported by a frame C C, and turn upon pivots *d*, *d*. The pivots are made of iron coated

he contact of the metals, for we know that a plate of silver plate of zinc, or of any other difficultly and easily oxida- etals, become negative and positive on contact. The ac- ation must be referred to *induction*, which takes place in ectrical column through the very thin stratum of air or and through water when that fluid is interposed between ıtes. Accordingly we observe that the apparatus is in the ion of the series of conductors with interposed air and of :yden phials, (198.) When the electric column is insulated tremities exhibit feeble negative and positive powers, but er extremity be connected with the ground, the electricity poles or extremities is greatly increased, as may be shown : increased divergence of the leaves of the electrometer then ensues.

Voltaic pile operates upon the principle of induction.

. As general changes in the form and constitution of matter onnected with its electrical states, it is obvious that electri- ıust be continually active in nature. Its effects are ex- l on a magnificent scale in the thunder-storm, which results he accumulation of electricity in the clouds, as was first mentally demonstrated by Dr Franklin, who also first d the advantage of pointed conductors as safeguards for ıgs.

Electricity continually active in nature.

. That arrangements of different organic substances are e of producing electrical effects, has been shown by vari- perimentalists. If the hind legs of a frog be placed upon ı plate, and the crural nerve dissected out of one made ımunicate with the other, it will be found, upon making ɔnal contacts with the remaining crural nerve, that the of the animal will be agitated at each contact. These ıstances have induced some physiologists to suppose that city may be concerned in some of the most recondite mena of vitality, and Dr Wollaston, Sir E. Home, and

Arrangements of organic substances admit of producing electrical effects.

Electricity concerned in the phenome-

Theories.

fluid existing in all matter, and exhibiting itself by the appearances which have been described, whenever its equilibrium is disturbed, presenting negative and positive electricity when deficient and when redundant. Others have plausibly argued for the presence of two fluids, distinct from each other. Others have considered the effects as referable to peculiar exertions of the attractive powers of matter, and have regarded the existence of any distinct fluid or form of matter to be as unnecessary to the explanation of the phenomena, as it is in the question concerning the cause of gravitation.

Experiments seeming to favour one more than another.

242. When the flame of a candle is placed between a positive and negative surface, it is urged towards the latter; a circumstance which has been explained upon the supposition of a current of electrical matter passing from the positive to the negative pole; indeed, it has been considered as demonstrating the existence of such a current of matter. But if the flame of phosphorus be substituted for that of a candle, it takes an opposite direction; and, instead of being attracted towards the negative, it bends to the positive surface. It has been shown that inflammable bodies are always attracted by negative surfaces, and acid bodies, and those in which the supporters of combustion prevail, are attracted by positive surfaces (218.) Hence the flame of the candle throwing off carbon, is directed to the negative pole, while that of phosphorus forming acid matter goes to the positive, consistently with the ordinary laws of electrochemical attraction.—*Philos. Trans.* 1814.

Experiments in opposition to electricity being material.

243. There are other experiments opposed to the idea that electricity is a material substance. If we discharge a Leyden phial through a quire of paper, the perforation is equally burred upon both sides, and not upon the negative side only, as would have been the case if any material body had gone through in that direction. The power seems to have come from the centre of the paper, as if one half of the quire had been attracted by the positive, and the other by the negative surface.

One of a contrary tendency.

244. When a pointed metallic wire is presented towards the conductor of the electrical machine, in a darkened room, a star of light is observed when the conductor is positive, but a brush of light when it is negative; a circumstance which has been referred to the reception of the electric fluid in the one case, and its escape in the other. In the Voltaic discharge the same appearances are evident upon the charcoal point, rays appearing to diverge from the negative conductor, while upon the positive a spot of bright light is perceptible. But these affections of light can scarcely be considered as indicating the emission or reception of any specific form of matter.

CHAPTER II.

OF ELECTRO NEGATIVE SUBSTANCES.*

245. THE substances belonging to this class are characterized by possessing very energetic powers of combination in respect to the simple inflammable bodies, and they are each of them capable of producing acids, whence they may also be termed *acidifying* principles. When their compounds are submitted to electro-chemical decomposition, these elements are attracted by the positive surface; hence their natural or inherent electrical states may be considered as negative.

Acidifying principles.

Electro negative.

These acidifying, electro-negative substances are three in number:

1. Oxygen.
2. Chlorine.
3. Iodine.

SECTION I. *Nomenclature.*

246. These bodies enter into combination with each other, and with other bodies, to be hereafter described, producing compounds, in an account of which it will be necessary to make use of the peculiar language of chemistry. The following examples may serve to give some idea of the principles of nomenclature generally adopted in chemistry.

Chemical nomenclature.

When any body unites with oxygen, whatever the product may be, the process is termed *oxygenation*. When only a certain portion of oxygen combines with other bodies, the product *not* acquiring *acid* properties, the process is termed *oxidation*, and the new compounds are usually distinguished by the termination *ide*,—as oxide of chlorine, *oxide* of nitrogen. In like manner similar combinations of chlorine and iodine are distinguished as *chlorides*, and *iodides*—thus we have *chloride* of sulphur, *iodide* of iron, &c.

When more than one compound of this kind is produced, the terminations *ous* and *ic* are used to designate the relative proportions of the electro-negative substances. Thus nitrogen forms two oxides; that containing the smallest proportion of oxygen is the *nitrous* oxide, that containing the largest the *nitric* oxide. The acid compounds are similarly designated, as *nitrous* and *nitric* acid; *sulphurous* and *sulphuric* acid; and where there are intermediate compounds the term *hypo* is occasionally added to the acid next above it in point of oxidizement. Thus, *hyposulphuric acid* signifies an acid compound intermediate between sulphurous and sulphuric acids; *hypophosphorous* acid, an acid containing less oxygen than the phosphorous acid.

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* By some termed *simple supporters of combustion*.

The different combinations of the metals with oxygen, are perhaps best distinguished by prefixing to the word *oxide* the first syllable of the Greek ordinal numerals, as originally proposed by Dr Thomson. Thus the *protoxide* of a metal will denote the compound containing a minimum of oxygen, or the first oxide which the metal is capable of forming; *deutoxide* will denote the second oxide of a metal, *&c.*; and when a metal is combined with the largest possible quantity of oxygen, the compound, if not acid, may be called *peroxide*. The same rule applies to the *chlorides* and *iodides*.

The acids terminating in *ous* produce compounds in which the termination *ite* is used; while those ending in *ic* form compounds in which the ending *ate* is used. Thus the combination of sulphurous acid and potassa, is a *sulphite* of potassa; that of sulphuric acid and potassa, a *sulphate* of potassa, *&c.*

When the same acid combines with more than one oxide of the same metal, the first syllable of the Greek ordinal numeral is in that case applied to the acid; thus, the *protosulphate* and *persulphate* of iron signify the combinations of sulphuric acid with the protoxide and peroxide of iron. The term *oxysulphate* is occasionally used to designate the latter compound, and in the same sense we speak of *oxynitrates*, *oxyphosphates*, *&c.* but the former mode of designation is less equivocal.

The compounds of the simple inflammable bodies with each other, and with the metals, are commonly designated by the termination *uret*, as *sulphuret* of phosphorus, *phosphuret* of carbon, *carburet* of iron, *&c.*

The terms *bi sulphuret*, *bi sulphate*, *bi phosphuret*, *bi phosphate*, *&c.* applied to compounds, imply that they contain twice the quantity of sulphur, sulphuric acid, phosphorus or phosphoric acid, existing in the respective sulphuret, sulphate, phosphuret and phosphate.

Gases. The term gas is applied to all permanently elastic fluids, except the atmosphere, to which the term air is appropriated.

Apparatus for gases 247. For performing the necessary experiments on gases, many articles of apparatus are necessary, consisting partly of vessels fitted for containing the materials that afford them, and partly of vessels adapted for the reception of gases, and for submitting them to experiment.

for procuring gases. Pl. 3. For procuring such gases as are producible without a very strong heat, glass bottles, furnished with ground stoppers and bent tubes, are sufficient, fig. 65. Of these, several will be required of different sizes and shapes, adapted to different purposes. If these cannot be procured, a Florence flask, with a cork perforated by a bent glass tube, or even by a tin pipe, will serve for obtaining some of the gases.

Those gases, that require, for their liberation, a red heat, may be procured by exposing to heat the substance capable of affording them, in coated earthen retorts or tubes; or in a gun barrel, the touch-hole of which has been accurately closed by an iron pin. To the mouth of the barrel must be affixed a glass tube, bent so as to convey the gases where it may be requisite.

Pl. 3.

A very convenient apparatus, for obtaining such gases as cannot be disengaged without a red heat, consists of a cast-iron retort, having a jointed metallic conducting tube fitted to it by grinding; by means of which the gas may be conveyed in any direction, and to any moderate distance. It is represented as placed, when in actual use, within the bars of a common fire-grate, fig. 66, *a*, *b*.*

for receiving gases.

For receiving the gases, glass jars, of various sizes, figs. 58, 67 and 68, are required, some of which should be furnished with necks at the top, fitted with ground stoppers. Others should be provided with brass caps, and screws, for the reception of air-cocks, fig. 69. Of these last, (the air-cocks) fig. 70, several will be found necessary; and, to some of them bladders, fig. 71, or elastic bottles, should be firmly tied, for the purpose of transferring gases. These jars will also be found extremely useful in experiments on the properties and effects of the gases. Some of them should be graduated into cubical inches, figs. 69 and 72.

Pneumatic trough.

To contain these jars, when in use, a vessel will be necessary, capable of holding a few gallons of water. This may either be of wood, fig. 67, *b*, if of considerable size; or, if small, of tin, japanned or painted. Fig. 67, *f f* exhibits a section of this apparatus, which has been termed the pneumato-chemical trough, or pneumatic cistern. Its size may vary with that of the jars employed; and, about two or three inches from the top, it should have a shelf, on which the jars may be placed, when filled with air, without the risk of being overset. In this shelf should be a few small holes, fig. 71, to which inverted funnels may be soldered †

Graduated tubes, &c.

A glass tube, about 18 inches long, and three quarters of an inch diameter, fig. 72, closed at one end, and divided into cubic inches and tenths of inches, will be required for ascertaining the purity of air by nitrous gas. It should be accompanied also with a small measure, containing about two cubic inches, and similarly graduated. For employing the solution of nitrous gas in liquid sulphate of iron, glass tubes, about five inches long, and half an inch wide, divided decimally, are also necessary. Besides these, the experimentalist should be furnished with air funnels, fig. 22, for transferring gases from wide to narrow vessels, Pl. 1.

Gazometer.

248. An apparatus, almost indispensable in experiments on this class of bodies, is a GAZOMETER, which enables the chemist to collect and to preserve large quantities of gas, with the aid of only a few pounds of water. In the form of this apparatus there is considerable variety; but, at present, I have no other

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* The wrought iron bottles in which quicksilver is imported form a convenient apparatus for this purpose, a gun barrel being screwed into the neck of the bottle.

† Fig. 73, Pl. 3, represents a very convenient form of this apparatus.

view than that of explaining its general construction and use. Pl. 3. It consists of an outer fixed vessel *d* (fig. 74) and an inner moveable one *c*, both of japanned iron. The latter slides easily up and down within the other, and is suspended by cords passing over pulleys, to which are attached the counterpoise, *ee*. To avoid the incumbrance of a great weight of water, the outer vessel *d* is made double, or is composed of two cylinders, the inner one of which is closed at the top and at the bottom. The space of only about half an inch is left between the two cylinders, as shown by the dotted lines. In this space, the vessel *c* may move freely up and down. The interval is filled with water as high as the top of the inner cylinder. The cup, or rim, at the top of the outer vessel, is to prevent the water from overflowing, when the vessel *c* is forcibly pressed down, in which situation it is placed, whenever gas is about to be collected. The gas enters from the vessel in which it is produced, by the communicating pipe *b*, and passes along the perpendicular pipe, marked by dotted lines in the centre, into the cavity of the vessel *c*, which continues rising till it is full.

To transfer the gas or to apply it to any purpose, the cock *b* is to be shut, and an empty bladder, or bottle of elastic gum, furnished with a stop cock, to be screwed on *a*. When the vessel *c* is pressed down with the hand, the gas passes down the central pipe, which it had before ascended, and its escape at *b* being prevented, it finds its way up a pipe which is fixed to the outer surface of the vessel, and which is terminated by the cock *a*. By means of an ivory mouth-piece screwed upon this cock, the gas, included in the instrument, may be respired; the nostrils being closed by the fingers. When it is required to transfer the gas into glass jars standing inverted in water, a crooked tube may be employed, one end of which is screwed upon the cock *b;* while the other aperture is brought under the inverted funnel, fixed into the shelf of the pneumatic trough. (See fig. 67.)

Several alterations have been made in the form of this apparatus; but they are principally such as add merely to its neatness and beauty, and not to its utility; and they render it less easy of explanation. The counterpoises *ee* are now, generally, concealed in the framing, and the vessel *c* is frequently made of glass.

Gas-holder. 249. When large quantities of gas are required, (as at a public lecture), the gas-holder, (fig. 75) will be found extremely useful. It is made of tinned iron-plate, jappanned both within and without. Two short pipes, *a* and *c*, terminated by cocks, proceed from its sides, and another, *b*, passes through the middle of the top or cover, to which it is soldered, and reaches within half an inch of the bottom. It will be found convenient also to have an air-cock with a very wide bore, fixed to the funnel at *b*. When gas is to be transferred into this vessel from the gazometer, the vessel is first completely filled with water through the funnel, the cock *a* being left open, and *c* shut. By means of a horizontal pipe, the aperture *a* is connected with *a* of the gazometer. The cock *b* being shut, *a* and *c* are open, and the vessel *c* of the gazometer (fig. 74,) gently pressed downwards with the hand. The gas then descends from the gazometer till the air-holder is full, which may be known by the water ceasing to escape through the cock *c*. All the cocks are then to be shut, and the vessel disunited. To apply this gas to any purpose, an empty bladder may be screwed on *a*; and water being poured through the funnel *b*, a corresponding quantity of gas is forced into the bladder. By lengthening the pipe *b*, the pressure of a column of water may be added: and the gas, being forced through *a* with considerable velocity, may be applied to the purpose of a blow-pipe, &c. &c. The apparatus admits of a variety of modifications. The most useful one appears to me to be that contrived by Mr Pepys, consisting chiefly in the addition of a shallow cistern (fig. 66, *c*) to the top of the air-holder, and of a glass register tube *f*, which shows the height of the water, and consequently the quantity of gas, in the vessel. When a jar is intended to be filled with gas from the reservoir, it is placed, filled with water, and inverted in the cistern *c*. The cocks 1 and 2 being opened, the water descends through the pipe attached to the latter, and the gas rises through the cock *e*. By raising the cistern *a* to a greater elevation, any degree of pressure may be obtained; and a blow-pipe may be screwed on the cock at the left side of the vessel.

Pl. 2.

Mercurial gazometers.

The gazometer, already described, is fitted only for the reception of gases that are confinable by water; because quicksilver would act on the tinning and solder of the vessel, and would not only be spoiled itself, but would destroy the apparatus. Yet an instrument of this kind, in which mercury can be employed, is peculiarly desirable, on account of the great weight of that fluid; and two varieties of the mercurial gazometer have therefore been invented. In that invented by Mr Pepys, the cistern for the mercury is of cast-iron. Mr Newman has lately joined a gazometer of this kind to an improved mercurial trough, by means of which the advantages of both are obtained with only 60 or 70 pounds of quicksilver,[*] (fig. 76.)

Pl. 3.

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[*] It is not more than 18 inches in length and height; and it is placed in a large japanned tray to collect scattered mercury.

When gas is to be collected in the gazometer, the beak of the retort is placed below the surface of the mercury, in the cup at the bottom of the apparatus, and having a bell-shaped vessel immersed in the mercury immediately over it. The trough has a cavity in the middle, large enough to fill a jar 10 inches long, and 2 1-2 wide; and there is a shelf on each side, three inches in width, to support vessels containing gas. Opposite to three indentations on the edge of the trough, are three holes in one of the shelves, into which the beaks of retorts liberating gas are to be introduced; or a sliding shelf with apertures may be fitted across the cavity for the same purpose. The gazometer is at one end. *a*, and sunk below the level of the trough. It is capable of containing 50 cubic inches. A tube, connected with the gazometer at the lower part is made to ascend, and passing up through the mercury in a corner of the trough, at about an inch above, it bends down again, and terminates beneath its surface. If the gas is contained in the gazometer it may be transferred to air-jars in the trough, by filling them with mercury, placing them over the end of the bent tube, and giving pressure to the gazometer. The air will pass from it along the tube into the jar. By the bend in

250. For those gases that are absorbed by water, a mercurial trough is necessary. For the mere exhibition of a few experiments on these condensible gases, a small wooden trough, eleven inches long, two wide, and two deep, cut out of a solid block of mahogany, (or soapstone) is sufficient. H. 1.

Pl. 3.

Apparatus for submitting gases to electricity.

251. The apparatus, required *for submitting gases to the action of electricity*, is shown in fig. 77; where *a* represents the knob of the prime conductor of an electrical machine; *b*, a Leyden jar, the ball of which is in contact with it, as when in the act of charging; and *c*, the tube standing inverted in mercury, and partly filled with gas. The mercury is contained in a strong wooden box *d*, to which is screwed the upright iron pillar *e*, with a sliding collar for securing the tube *c* in a perpendicular position. When the jar *b* is charged to a certain intensity, it discharges itself between the knob *a* and the small ball *i*, which, with the wire connected with it, may be occasionally fitted on the top of the tube *c*. The strength of the shocks is regulated by the distance between *a* and *i*.

By the same apparatus, inflammable mixtures of gases may be exploded by electricity. In this case, however, the jar *b* is unnecessary, a spark received by *i* from *a* being sufficient to kindle the mixture.

Methods of transferring gases,

252. Previously to undertaking experiments on the gases, it may be well for an unpractised experimentalist to accustom himself to the dexterous management of gases, by transferring common air from one vessel to another of different sizes.

1. When a glass jar, closed at one end, is filled with water, and held with its mouth downwards, in however small a quantity of water, the fluid is retained in its place by the pressure of the atmosphere on the surface of the exterior water. Fill in this manner, and invert, on the shelf of the pneumatic trough, one of the jars, which is furnished with a stopper (fig. 58). The water will remain in the jar so long as the stopper is closed; but immediately on removing it, the water will descend to the same level within as without; for it is now pressed, equally upwards and downwards, by the atmosphere, and falls therefore in consequence of its own gravity.

Pl. 3.

2. Place the jar, filled with water and inverted, over one of the funnels of the shelf of the pneumatic trough. Then take another jar, filled (as it will be of course) with atmospherical air. Place the latter with its mouth on the surface of the water; and on pressing it in the same position below the surface, the included air will remain in its situation. Bring the mouth of

the tube, the mercury is prevented from passing into the lower part of the gazometer, while at the same time the gas is allowed a free passage. All inconvenience is prevented by means of a stop-cock, which shuts off the communication between the receiver and the trough, preventing at the same time the escape of air from the gazometer, and of mercury into it. A sliding shelf is fixed beneath the trough to support a spirit-lamp under a retort, or for other purposes. A detonating tube and spring are also attached to the apparatus by a clamp and screws, and may be fixed on any side of the trough. The whole apparatus is of iron, excepting sometimes the pillars which support it, and which may be of brass.

the jar beneath the funnel in the shelf, and incline it gradually. The air will now rise in bubbles, through the funnel, into the upper jar, and will expel the water from it into the trough.

3. Let one of the jars, provided with a stop-cock at the top, be placed full of air on the shelf of the trough. Screw upon it an empty bladder; open the communication between the jar and the bladder, and press the former into the water, fig. 71. The air will then pass into the bladder, till it is filled; and when the bladder is removed from the jar, and a pipe screwed upon it, the air may be again transferred into a jar inverted in water. Directions for practice.

4. For the purpose of transferring gases from a wide vessel standing over water, into a small tube filled with and inverted in mercury, I have long used the following contrivance of Mr Cavendish. A tube, eight or ten inches long, and of very small diameter, is drawn out to a fine bore, and bent at one end, so as to resemble the Italic letter *l*. The point is then immersed in quicksilver, which is drawn into the tube till it is filled, by the action of the mouth. Placing the finger over the aperture at the straight end, the tube is next conveyed through the water, with the bent end uppermost, into an inverted jar of gas. When the finger is removed, the quicksilver falls from the tube into the trough, or into a cup placed to receive it, and the tube is filled with the gas. The whole of the quicksilver, however, must not be allowed to escape; but a column must be left, three or four inches long, and must be kept in its place by the finger. Remove the tube from the water; let an assistant dry it with blotting paper; and introduce the point of the bent end into the aperture of the tube standing over quicksilver. On withdrawing the finger from that aperture which is now uppermost, the pressure of the column of quicksilver, added to the weight of the atmosphere, will force the gas from the bent tube into the one standing in the mercurial trough.

253. The method of *weighing gases* is very simple, and easily practised. For this purpose, however, it is necessary to be provided with a good air-pump; and with a globe or flask, furnished with a brass cap and air-cock, as shown fig. 69, *b*. A graduated receiver is also required, to which an air-cock is adapted, as shown at *a*. Method of weighing gases.

Supposing the receiver *a* to be filled with any gas, the weight of which is to be ascertained, we screw the cock of the vessel *b* on the transfer plate of an air-pump, and exhaust it as completely as possible. The weight of the exhausted vessel is then very accurately taken, even to a small fraction of a grain; and it is screwed upon the air-cock of the receiver *a*. On opening both cocks, the last of which should be turned very gradually, the gas ascends from the vessel *a*; and the quantity, which enters into the flask, is known by the graduated scale on *a*. On weighing the vessel a second time, we ascertain how many grains have been admitted. If we have operated on common air, we shall find its weight to be at the rate of about 30,5 grains Pl. 3.

to 100 cubic inches. The same quantity of oxygen gas will weigh about 34 grains, (33,8888 T.) and of carbonic acid gas, upwards of 47 grains, (46,5972 T.)

Circumstances to be attended to.

254. In experiments of this kind, it is necessary either to operate with the barometer at 30 inches, and the thermometer at 60° Fahrenheit, or to reduce the volume of gas employed to that pressure and temperature, by rules which are given below.[*] Great care is to be taken, also, not to warm any of the vessels by contact with the hands, from which they should be defended by a glove. On opening the communication between

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[*] *Rules for reducing the Volume of Gases to a mean Height of the Barometer, and mean Temperature.*

i. *From the space occupied by any quantity of gas under an observed degree of pressure, to infer what its volume would be under the mean height of the barometer, taking this at 30 inches, as is now most usual.*

This is done by the rule of proportion; for, as the mean height is to the observed height, so is the observed volume to the volume required. For example, if we wish to know what space would be filled, under a pressure of 30 inches of mercury, by a quantity of gas, which fills 100 inches, when the barometer is 29 inches.

30 : 29 : : 100 : 96,66.

The 100 inches would, therefore, be reduced to 96,66.

ii. *To estimate what would be the volume of a portion of gas, if brought to the temperature of 60° Fahrenheit.*

Divide the whole quantity of gas by 480; the quotient will show the amount of its expansion or contraction by each degree of Fahrenheit's thermometer. Multiply this by the number of degrees, which the gas exceeds, or falls below 60°. If the temperature of the gas be above 60°, subtract, or if below 60°, add, the product to the absolute quantity of gas; and the remainder in the first case, or sum in the second, will be the answer. Thus, to find what space 100 cubic inches of gas at 50° would occupy if raised to 60°, divide 100 by 480: the quotient 0,208 multiplied by 10 gives 2,08, which added to 100 gives 102,08, the answer required. If the temperature had been 70°, and we had wished to know the volume which the gas would have occupied at 60°, the same number 2,08 must have been subtracted from 100, and 97,92 would have been the answer.

iii. In some cases, it is necessary to make a double correction, or *to bring the gas to a mean both of the barometer and thermometer.* We must then first correct the temperature, and afterwards the pressure. Thus, to know what space 100 inches of gas at 70° Fahrenheit, and 29 inches barometer would fill at 60° Fahrenheit and 30 inches barometer, we first reduce the 100 inches, by the second process, to 97,92. Then by the first,

30 : 29 : : 97,92 : 94,63.

Or 100 inches thus corrected, would be only 94,63.

iv. *To ascertain what would be the absolute weight of a given volume of gas at a mean temperature, from the known weight of an equal volume at any other temperatare:* first, find by the second process what would be its bulk at a mean temperature; and then say, as the corrected bulk is to the actual weight, so is the observed bulk to the number required. Thus, if we have 100 cubic inches of gas weighing 50 grains at 50° Fahrenheit, if the temperature were raised to 60° they would expand to 102,08. And

102,08 : 50 : : 100 : 49.

Therefore 100 inches of the same gas at 60° would weigh 49 grains.

v. *To learn the absolute weight of a given volume of gas under a mean pressure, from its known weight under an observed pressure,* say as the observed pressure is to the mean pressure, so is the observed weight to the corrected weight. For example, having 100 inches of gas which weigh 50 grains under a pressure of 29 inches, to know what 100 inches of the same gas would weigh, the barometer being 30 inches,

29 : 30 : : 50 : 51,72.

Then 100 inches of the same gas, under 30 inches pressure, would weigh 51,72 grains.

vi. In some cases it is necessary to combine the two last calculations Thus, if 100 inches of gas at 50° Fahrenheit, and under 29 inches pressure, weigh 50 grains, to find what would be the weight of 100 inches at 60° Fahrenheit, and under 30 inches of the barometer, first correct the temperature which reduces the weight to 49 grains. Then,

29 : 30 : : 49 : 50,7.

100 inches, therefore, would weigh 50,7 grains. H. 1. 23.

For Mr. Dalton's formula for the corrections for moisture in gases, see H. 1, 25.

the receiver and the exhausted globe, if any water be lodged in the air-cock attached to the former, it will be forcibly driven into the globe, and the experiment will be frustrated. This may be avoided by using great care in filling the receiver with water, before passing into it the gas under examination.

Method of determining the specific gravity of gases.

255. The specific gravity of any gas compared with common air is readily known, when we have once determined its absolute weight. Thus, if 100 cubic inches of air weigh 30,5 grains, and the same quantity of oxygen gas weighs 33,8888 grains, we say,

30,5 : 33,8888 : : 1,000 : 1,1111.

The specific gravity of oxygen gas will therefore be as 1,1111 to 1,000. We may determine, also, the specific gravity of gases, more simply, by weighing the flask, first when full of common air, and again when exhausted; and afterwards by admitting into it as much of the gas under examination as it will receive; and weighing it a third time. Now as the loss between the first and second weighing is to the gain of weight on admitting the gas, so is common air to the gas whose specific gravity we are estimating. Supposing for example, that by exhausting the flask it loses 30,5 grains, and that by admitting carbonic acid it gains 46,5972; then

30,5 : 46,5972 : : 1,000 : 1,5277.

The specific gravity of carbonic acid is therefore 1,5277, air being taken at 1,000. And knowing its specific gravity, we can, without any further experiment, determine the weight of 100 cubic inches of carbonic acid; for as the specific gravity of air is to that of carbonic acid, so is 30,5 to the number required; or

1,000 : 1,5277 : : 30,5 : 46,5948.

One hundred inches of carbonic acid, therefore, will weigh 46,5948 grains. H. 1. 21.

SECTION II. *Of Oxygen.*

256. Oxygen has never been obtained in a state of complete separation. In the state of gas, it is combined with caloric, and probably with light and electricity. It was discovered in 1774 by Dr Priestley who gave it the name of *dephlogisticated* air.

Time of discovery.

257. This gas may be obtained from various substances. 1. From the black oxide of manganese, heated to redness in a gun-barrel, or in an iron retort; or from the same oxide, heated by a lamp in a retort, fig. 67, *c*, or gas bottle, fig. 65, with half its weight of strong sulphuric acid. One pound of manganese is capable of furnishing from 40 to 50 wine pints of gas. But as manganese is often contaminated with a small proportion of carbonate of lime, it is advisable, before using it, to wash it with muriatic

Method of obtaining oxygen gas.

Pl. 3.

acid diluted with 15 or 20 parts of water; then with distilled water; and afterwards to dry it at a moderate heat.

2. From the red oxide of lead (the common red lead) used by painters, heated either with or without half its weight of concentrated sulphuric acid.

3. From various other oxides, as will be hereafter mentioned.

4. From nitrate of potash (common saltpetre) made red-hot in a gun-barrel, or in a coated earthen retort.

5. From chlorate of potash. heated in a small glass retort, over an Argand's lamp. The oxygen gas thus produced is much purer than that obtained in any other mode, especially the last portions, which should be kept separate. It will be found, also, to be much less contaminated with common air, if heated in a small matrass, which is best when of green glass. The chlorate of potash may be introduced while the tube is straight, which allows us to make use of one of very small diameter, after this it may be bent by a spirit lamp, as in fig. 49.

Pl. 2.

258. All these substances, after having yielded oxygen gas, are found considerably diminished in weight; and calculating each cubic inch of gas to be equal to one-third of a grain, the loss of weight will be found pretty exactly equivalent to that of gas generated.

Properties of oxygen gas.

259. Oxygen gas is insipid, colourless and inodorous. It is so sparingly absorbed by water, that when agitated in contact with it, no perceptible diminution takes place. It is rather heavier than common air; its specific gravity is 16, hydrogen being assumed = 1.[*] 100 cubical inches at mean temperature and pressure weigh 33,8888 grains. (T.)

Becomes luminous by compression.

260. It refracts the rays of light less than any other gas. When suddenly and strongly compressed, not only heat is evolved, but the *gas becomes luminous*, a property belonging to no other simple gas except chlorine. H. 1. 207.

Supports respiration.

261. It is a powerful supporter of respiration and combustion. A small animal, confined in oxygen gas, lives thrice as long as when confined in the same bulk of common air.—This effect seems connected with the absorption of oxygen by the blood.

Exp.

—Pass up a little dark-coloured blood into a jar partly filled with oxygen gas, and standing over mercury. The gas will be in part absorbed, and the colour of the blood will be changed to a bright and florid red. This change to red may be shown, by putting a little blood into a common vial fillled with oxygen gas, and shaking it up. H.

and combustion.

262. All combustible bodies burn in oxygen gas with greatly increased splendour.

Exp.

Pl. 2.

A lighted wax taper, fixed to an iron wire, and plunged into a vessel of this gas, burns with great brilliancy, fig. 50. If the taper be blown out, and let down into a vessel of the gas while the snuff remains red-hot, it instantly rekindles, with a slight explosion.

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[*] Its specific gravity according to the latest experiments of Thomson, is 1,1111, that of common air being taken as 1.

Exp.

A red-hot bit of charcoal, fastened to a copper wire, and immersed in the gas, throws out beautiful sparks.

Exp.

Combustion of phosphorus.

Pl. 2.

The light of phosphorus, burnt in this gas, is the brightest that can be in any mode produced. If we except perhaps the ignition of charcoal by voltaic electricity. Let the phosphorus be placed in a small hemispherical tin cup, which may be raised by means of the wire stand, fig. 36, two or three inches above the surface of water contained in a broad shallow dish. Fill a bell-shaped receiver, having an open neck at the top, to which a stopper is ground, with oxygen gas; and, as it stands inverted in water, press a circular piece of pasteboard, rather exceeding the jar in diameter, over its mouth. Cover the phosphorus instantly with the jar of oxygen gas, retaining the pasteboard in its place, till the jar is immediately over the cup. When this has been skilfully managed, a very small portion only of the gas will escape. The stopper may now be removed, when the water will rise to the same level within as without the jar, and the phosphorus may be kindled by a heated copper wire.

Exp.

Of zinc and other metals.

Substitute for the phosphorus a small ball formed of turnings of zinc, in which about a grain of phosphorus is to be enclosed. Set fire to the phosphorus as before. The zinc will be inflamed, and will burn with a beautiful white light. A similar experiment may be made with metallic arsenic, which may be moistened with spirit of turpentine. The filings of various metals may also be inflamed, by placing them in a small cavity, formed in a piece of charcoal, igniting the charcoal, and blowing, on the part containing the metal, a stream of oxygen gas from a bladder, or the gas-holder, fig. 66, *d*.

Exp.

Procure some thin harpsichord wire, and twist it round a slender rod of iron or glass, so as to coil it up in a spiral form. Then withdraw the rod, and tie a little thread or flax round one end of the wire, for about one 20th of an inch; which end is to be dipped into melted sulphur. The other end of the wire is to be fixed into a cork; so that the spiral may hang vertically (fig. 78). Fill, also, with oxygen gas, a bottle capable of holding about a quart, and set it with its mouth upwards. Then light the sulphur and introduce the wire into the bottle of gas, suspending it by the cork. The iron will burn with a most brilliant light, throwing out a number of sparks, which fall to the bottom of the bottle, and generally break it. This accident, however, may frequently be prevented by pouring sand into the bottle, so as to lie about half an inch deep on the bottom. According to Mr Accum,* a thick piece of iron or steel, such as a file, if made sharp pointed, may be burnt in oxygen gas. A small bit of wood is to be stuck upon its extremity, and set on fire, previously to immersion in the gas.

Exp.

A little of Homberg's pyrophorus, a substance to be hereafter described, when poured into a bottle full of this gas, immediately flashes like inflamed gunpowder. H.1. 208.

* Nicholson's Journal. 8vo. i. 320.

Its volume diminished during combustion.]

263. During every combustion in oxygen gas, the gas suffers a considerable diminution.—To exhibit this, experimentally, in a manner perfectly free from all sources of error, would require such an apparatus as few beside adepts in chemistry are likely to possess. The apparatus required for this purpose is described in the 6th chapter of Lavoisier's Elements. The fact may, however, be shown, less accurately by the combustion of phosphorus, in the manner which has been already described. The first effect of the combustion will be a depression of the water within the jar; but when the combustion has ceased, and the vessel has cooled, a considerable absorption will be found to have ensued.

Those persons who are possessed of a mercurial apparatus may repeat this experiment in a less exceptionable manner. On the surface of the quicksilver, let a small hemispherical cup float, made of untinned sheet-iron; and, in order to keep it from the sides of the jar, it may rest on a wire stand, shaped like the figure 21. Let a jar, the height and diameter of which must be regulated by the size of the mercurial trough, be filled with oxygen gas over water and be removed, by means of a piece of pasteboard, as before described, to the mercurial bath, inverting it dexterously over the tin cup. If the phosphorus had been previously set on fire, a large quantity of the gas, expanded by the heat, would have escaped, and would have prevented the accurate measurement of the absorption. After drying the surface of the mercury within the jar by blotting paper, a portion of the included gas must, therefore, be removed. This is done by an inverted syphon, one leg of which is to be introduced (in the same manner as is shown at fig. 79, *g*) within the jar, before placing it over the mercury; and the gas will be forced through the open extremity of the other, when the jar is pressed down into the quicksilver. When the proper quantity has been expelled, remove the syphon. The cup containing the phosphorus, will thus rest on the surface of the quicksilver within the jar, and above the level of the mercury without. The phosphorus is to be inflamed by passing a crooked iron wire, made red hot, through the quicksilver. On the first impression of the heat, arising from its combustion, the included gas will be considerably expanded; but, when the phosphorus has ceased to burn, a considerable absorption will be found to have taken place, the amount of which may be measured by ascertaining the height of the quicksilver, within the jar, before and after the experiment. The quantity of phosphorus employed should be very small, and should not bear a greater proportion than that of 10 grains to each pint of gas; otherwise the combustion will go on so far as to endanger the breaking of the jar, by the approach of the inflamed phosphorus.

Pl. 1.

In this process, a white dense vapour is produced, which condenses on the inner surface of the jar in solid flakes. This substance has strongly acid properties; and, being formed by the union of oxygen with phosphorus, is termed the phosphoric acid.

264. The diminution of the volume of oxygen gas, by the combustion of other bodies, may be ascertained in a similar manner. When the substance employed is not easily set on fire, it is proper to enclose, along and in contact with it, a small bit of phosphorus, the combustion of which excites sufficient heat to inflame iron-turnings, charcoal, &c. In the instance of charcoal, however, though that substance undergoes combustion, no absorption ensues; because, as will appear in the sequel, the product is a gas, occupying exactly the same bulk as the oxygen gas submitted to experiment. H. 1. 210.

265. The phenomena of combustion were referred b
and his associates, to a peculiar principle which they ca
phlogiston; it was supposed to exist in all combustibles, a
combustion was said to depend upon its separation; but this explanation was absurdly at variance with the well-known fact, that bodies during combustion increase in weight.

Bodies increase in weight.

266. All bodies, by combustion in oxygen gas, acquire an addition to their weight; and that the increase is in proportion to the quantity of gas absorbed, viz. about one third of a grain for every cubic inch of gas.—To prove this by experiment, requires also a complicated apparatus.

Exp.

But sufficient evidence of this fact may be obtained by the following very simple experiment. Fill the bowl of a tobacco-pipe with iron wire coiled spirally, and of known weight: let the end of the pipe be slipped into a brass tube, which is screwed to a bladder filled with oxygen gas: heat the bowl of the pipe, and its contents, to redness in the fire, and then force through it a stream of oxygen gas from the bladder. The iron wire will burn; will be rapidly oxidized; and will be found, when weighed, to be considerably heavier than before. When completely oxidized in this mode, 100 parts of iron wire gain an addition of about 30.

Theory of Lavoisier.

267. After the discovery of oxygen gas, it was adopted by Lavoisier as the universal supporter of combustion. The basis of the gas was supposed to unite to the combustible, and the heat and light which it before contained in the gaseous state, were said to be evolved in the form of flame. But in this case, several requisites are not fulfilled; the light depends upon the combustible, and not upon the quantity of oxygen consumed; and there are very numerous instances of combustion in which oxygen, instead of being solidified, becomes gaseous during the operation; and, lastly, in others, no oxygen whatever is present. Combustion, therefore, cannot be regarded as dependent upon any peculiar principle or form of matter, but must be considered as a general result of intense chemical action. It may be connected with the electrical energies of bodies; for all bodies which powerfully act upon each other, are in the opposite electrical states of positive and negative; and the evolution

Insufficient.

Combustion may be connected with the electrical energies of bodies.

of heat and light may depend upon the annihilation of these opposite states, which happens whenever they combine.* B.

Three classes of products.

268. The substances, capable of uniting with oxygen, afford one or other of the following products; 1st, an *acid;* 2dly, an *alkali* or *earth;* or 3dly, an *oxide.*

Oxygen not essential to acidity.

269. But oxygen is not essential to the acidity of a compound, for some bodies are rendered acid by union with chlorine, others by hydrogen; and the theory of Lavoisier which considered oxygen as the essential principle of acidity, and in conformity to which its present name was assigned to it† can no longer be received as correct. The alkalis and earths are chiefly distinguished, by acting as bases, with which the acids combine, with the loss generally of the separate characters of each (34). In some respects the alkalis agree with the 3d class of compounds, viz. oxides.

In many instances, a combustible body, which affords an acid when united with a certain quantity of oxygen, gives an *oxide* when combined with a less quantity; and the acid may be brought back to the state of an oxide by separating part of its oxygen. A few of the metals also, combined with a small proportion of oxygen, give oxides capable of uniting with acids and of composing *salts*, and again united with more oxygen yield an acid which is susceptible, with alkalis and earths, of forming saline compounds. H. 1. 212.

SECTION III. *Of Chlorine.*

Time of discovering Synonyms.

270. Chlorine was discovered by Scheele in 1774; it was called by him *dephlogisticated marine acid.* The term *oxymuriatic* acid was afterwards applied to it by the French chemists.

Method of obtaining chlorine.

271. Chlorine gas may be formed by either of the following processes:

1. Into a stoppered retort introduce eight ounces of liquid muriatic acid, sp. gr. 1,160, and four ounces of finely powdered manganese, and apply the heat of a lamp. A gas will be produced which may be received, in the usual manner over water, of the temperature of 80° or 90°. From these materials about 160 cubical inches may be obtained.

2. Grind together in a mortar eight ounces of muriate of soda (common salt) with three ounces of powdered manganese; put them into a stoppered retort. On applying a gentle heat, gas will be produced, as in process 1. But as the gas is absorbed by contact with cold water, though not rapidly, it should be received,

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* There can be little doubt, that the heat as well as the light, has its origin partly from the oxygen gas, and partly from the combustible body; but the precise quantity due to each can scarcely be considered as yet determined.—Lavoisier has endeavoured to prove that a given weight of oxygen abandons very different quantities of heat, when combined with different inflammable bodies. H.

† From ὀξυς, acid, and γεινομαι, to generate.

when it is intended to be kept, in bottles filled with, and inverted in, water of the temperature of 80° or 90° Fahrenheit, and provided with accurately ground stoppers. It will be found also much to diminish the loss of gas by absorption, if it be made to issue from a gas bottle, the tube of which is sufficiently long to reach nearly to the bottom of the inverted receiving bottle, as in fig. 80.) The stopper must be introduced under water, while the water remains quite full of the gas and inverted, and no water must be left in the bottle, along with the gas.*

Properties of chlorine.

Characteristics.

272. Chlorine is an elastic, gaseous fluid, it has a pungent disagreeable odour, and is highly injurious when respired even largely diluted with atmospheric air. Its colour is greenish yellow, hence its name.†

Destroys vegetable colours.

Exp.

273. Chlorine gas, in its ordinary state, destroys all vegetable colours. This may be shown by passing, into the gas confined by water, a piece of paper stained with litmus, the colour of which will immediately disappear. Hence the application of this gas to the purpose of bleaching, its power of effecting which may be shown by confining, in the gas, a pattern of unbleached calico, which has been previously boiled in a weak solution of caustic potash, and then washed in water, but not dried. Chlorine gas, however, which has been carefully dried by solid chloride of calcium, and into which perfectly dry litmus paper is introduced, produces no change of colour in the litmus, a sufficient proof that its bleaching power depends on the presence and decomposition of water. H. 1. 215.

Hydrate of chlorine.

274. Dry chlorine, is not condensible by a cold of—40° F.; but either the moist gas, or a solution of chlorine in water, crystallizes at + 40. The crystals may be obtained by introducing, into a clean bottle of the gas, a little water, and exposing the bottle for a few days to a temperature at or below freezing, in a dark place. A solid compound of chlorine and water is formed, which, in a day or two, sublimes and shoots into delicate prismatic needles, extending from half an inch to two inches into the atmosphere of the bottle. When these crystals are put into alcohol, they increase its temperature 8° or 10°, a rapid action takes place, with the formation of much ether and muriatic acid, and a small proportion of a triple compound of chlorine, hydrogen, and carbon. These crystals, which were first obtained by Mr Faraday, appear to be composed of chlorine 27. 7 + water 72. 3=100.‡—*Annals of Philos. 2d Series, V.* 304.

Liquefaction of chlorine.

275. When a portion of this solid and dried hydrate in a small bent tube, hermetically sealed, is heated to 100° a yellow vapour forms which condenses in the cool part of the tube into a

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*In some chemical works the proportions of 1 part of manganese, 3 of salt, and 2 of sulphuric acid are recommended, but this mixture is apt to boil over into the neck of the retort.

† From χλωρος, green.

‡ This nearly accords with 10 atoms water=90 (hydrogen=1) + 1 atom chlorine=36. H. According to Dr Thomson it is a *decahydrate*; 10 atoms water=11. 25 (oxygen=1) + 1 atom chlorine=4. 5.

liquid heavier than water. On relieving the pressure by breaking the tube, the chlorine instantly assumes the state of gas. These facts were discovered by Mr Faraday. (*See Boston Jour. of Philos. Vol.* 1. *p.* 516.)

276. When chlorine is suddenly and considerably condensed by mechanical pressure, not only heat is evolved, as from all other gases, but light also. It is not altered by exposure to Pl. 2. very high temperatures. By means of the apparatus, fig. Unaltered in high temperatures. 43, Sir H. Davy exposed it to the continued action of charcoal intensely ignited by Voltaic electricity, without the smallest change in its properties.

Exp. A glass globe *a*, of about four inches' diameter, has at its upper part a sliding wire passing air-tight through a ground collar *b*, to the lower end of which is attached a piece of well-burned charcoal *c*: at the bottom is a stop-cock supporting a brass pincers, in which is another pointed piece of charcoal *c*; the globe is exhausted upon the air-pump, filled with chlorine, and the stop-cock *d* and sliding wire *e* attached to the extremities of the Voltaic apparatus; the charcoal points are then brought into contact by pushing down the upper wire, and they are thus retained as long as necessary in intense ignition. B.

Specific gravity. 277. Chlorine is heavier than common air. Its specific gravity is (according to Dr Thomson) 2. 5, (air=1) which, taking his statement of the sp. gr. of hydrogen, viz. 0,0694 would make it 36 times the weight of hydrogen. From other data it had been calculated to be only 33½ times heavier than hydrogen. H. 100 cubic inches weigh 76. 25 grains. T.

Absorbed by water. 278. At the temperature of 60°, water dissolves or absorbs two volumes of chlorine. The best method of effecting the impregnation of water with this gas is by means of a Woulfe's apparatus, (fig. 81)* the bottles being surrounded by ice-cold water.

Solution in water. 279. The watery solution if perfectly free from common muriatic acid, has not the usual taste of an acid, but an astringent

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* In several instances, the substance raised by distillation is partly a condensible liquid, and partly a gas, which is not condensed, till it is brought into contact with water. To effect this double purpose, a series of receivers, termed *Woulfe's apparatus*, is employed. The first receiver (*b*, fig. 81) has a right-angled glass tube, open at both ends, fixed into its tubulure; and the other extremity of the tube is made to terminate beneath the surface of distilled water, contained, as high as the horizontal dotted line, in the three-necked bottle *c*. From another neck of this bottle, a second pipe proceeds, which ends, like the first, under water, contained in a second bottle *d*. To the central neck, a straight tube, open at both ends, is fixed, so that its lower end may be a little beneath the surface of the liquid. Of these bottles any number may be employed that is thought necessary.

The materials being introduced into the retort, the arrangement completed, and the joints secured, the distillation is begun. The condensable vapour collects in a liquid form in the balloon *b*, while the evolved gas passes through the bent pipe, beneath the surface of the water in *c*, which continues to absorb it till saturated. When the water of the first bottle can absorb no more, the gas passes, uncondensed, through the second right-angled tube, into the water of the second bottle, which, in its turn, becomes saturated. Any gas that may be produced, which is not absorbable by water, escapes through the bent tube *e*, and may be collected, if necessary.

Supposing the bottles to be destitute of the middle necks, and, consequently, without the perpendicular tubes, the process would be liable to be interrupted by an accident: for if, in consequence of a diminished temperature, an absorption or condensation of gas should take place, in the retort *a*, and, of course, in the balloon *b*, it must necessarily ensue that the water of the bottles *c* and *d* would be forced, by the pressure of the atmosphere, into the balloon, and possibly into the retort; but, with the addition ous. Its purity from muriatic acid may be ascertained by a solution of nitrate of mercury, which is not precipitated by pure chlorine.

Properties.

The watery solution has the colour and peculiar smell of the gas, and has a similar property of discharging vegetable colours. Hence it may be employed in bleaching. H.

Its use in bleaching.

This may be illustrated by placing a few strips of dyed linen cloth of different colours in a solution of chlorine, the colours will soon be discharged.

Effect of cold.

When the watery solution of chlorine is exposed to a temperature only a little above that of freezing water, the gas, which is combined with it, separates in the form of a liquid, heavier than water.

of heat.

280. Chlorine is not altered by the temperature of boiling water; for its solution may be raised in distillation, and again condensed without change.

of the sun's rays.

281. When the solution of chlorine in water is exposed to the direct rays of the sun, oxygen gas is obtained, and the acid passes to the state of muriatic acid.

Decomposed by Voltaic Electricity.

282. Placed in the current of the electric fluid, the chlorine, and the oxygen of the water, arrange themselves at the positive, and the hydrogen at the negative pole.

Exp.

283 When a burning taper is immersed in a jar of chlorine, the flame becomes red, a dense smoke arises, and the taper is soon extinguished.

Union with combustibles.

Many bodies, such as phosphorus, and several of the metals, when in a finely divided state, are spontaneously ignited by chlorine and burn in it with much brilliancy.* In these cases binary compounds result, some of which, like those of oxygen, are possessed of acid properties: others are not acid: and such compounds with oxygen being called *oxides*, those which chlorine forms may be termed *chlorides*.

Formerly considered as a compound.

284. Chlorine was once regarded as composed of oxygen and muriatic acid, a fallacy arising from the presence of water, and which will be rendered more intelligible under the head *Muriatic Acid.* B.

Euchlorine gas.

285. *Chlorine and Oxygen.*—When chlorate of potash (a salt which will be afterwards described) is distilled, at a gentle heat, with weak muriatic acid, a gas may be collected over mercury, which is found to differ essentially from chlorine. Its colour has a dense tint of brilliant yellow green; and its smell resembles that of burnt sugar, mixed with the peculiar smell of chlorine. Water takes up eight or ten times its volume,

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of the central tubes, a sufficient quantity of air rushes through them to supply any accidental vacuum. This inconvenience, however, is still more conveniently obviated by Welther's tube of safety (fig. 82 b, c,) which supersedes the expediency of three-necked bottles. The apparatus being adjusted, as shown by the figure, a small quantity of water is poured into the funnel, so as to about half fill the ball *b*. When any absorption happens, the fluid rises in the ball, till none remains in the tube, when a quantity of air immediately rushes in. On the other hand, no gas can escape, because any pressure from within is instantly followed by the formation of a high column of liquid in the perpendicular part, which resists the egress of gas.

* The temperature of the gas should not be much below 70° Fahrenheit.

and acquires an orange tint. It has been called by its discoverer, Sir H. Davy, *Euchloric gas*, or simply *Euchlorine.* Gay-Lussac has proposed for it the name of oxide of chlorine; but it may, with more propriety, be called *Protoxide of Chlorine.*

Composition.

286. Euchlorine explodes by a gentle heat, applied to the vessel which contains it, and five parts in volume become six, consisting of a mixture of oxygen and chlorine gases, in such proportions, that euchlorine must be composed of two in volume of chlorine and one of oxygen, the latter being condensed into half its bulk, or by weight of

Chlorine	81.44	100.
Oxygen	18.56	22.79
	100.	

These proportions indicate, that euchlorine is constituted of one atom of chlorine $= 36 +$ one atom of oxygen $= 8$ and hence its atom must weigh 44, hydrogen being $= 1$.

When detonated with twice its volume of hydrogen gas, there is a condensation of more than two-thirds of the mixture, and liquid muriatic acid is formed.

Properties.

287. Mercury has no action on euchlorine at common temperatures, antimony and copper burn in it, if introduced previously heated. Sulphur and phosphorus decompose it; and charcoal, already ignited, burns in it with a dull red light. Nitrous gas condenses it with red fumes.

288. Euchlorine destroys vegetable colours; but it first gives the blue a tint of red.

Phenomenon attending its decomposition.

289. In almost all cases of vivid combustion, there is a condensation of the bodies which unite; but in the decomposition of euchlorine by heat, we have the remarkable phenomenon of an explosion, accompanied with heat and light, and an expansion of the elements, which are separated from each other. H. 1. 217.

Peroxide of chlorine.

290. *Deutoxide or Per-oxide of Chlorine.*—Another compound of chlorine and oxygen, containing a larger proportion, than euchlorine, of the latter element, has been discovered by Sir H. Davy,* and has since been made the subject of a series of experiments by Count Stadion of Vienna.† As it exhibits no acid properties, it may be called *per-oxide of chlorine.*

Method of obtaining it.

291. To procure it, 50 or 60 grains of the powdered chlorate of potash, are to be mixed with a small quantity of concentrated sulphuric acid. When thoroughly incorporated, a solid mass will result, of a bright orange colour. This is to be introduced into a very small retort of glass, or a bent tube, which is to be exposed to the heat of water gradually warmed, but prevented from attaining the boiling point, by an admixture of spirit of wine. The gas may be received over mercury, on which it has no action at common temperatures.

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* Phil. Trans. 1815, Part II.

† Thomson's Annals, ix. 22.

Properties.

292. It has a lively yellow colour, much more brilliant than that of euchlorine; is much more rapidly absorbed by water; and has a peculiar aromatic smell, not mixed with any smell of chlorine. According to Davy, it destroys vegetable blue colours, without first reddening them; but Count Stadion asserts, that it does not change blue paper. When heated to about the temperature of 212° Fahrenheit, or, according to Count Stadion, to between 112° and 114°, it explodes with more violence, and a greater expansion of volume, than euchlorine, producing much light. After explosion over mercury, from 2,7 to 2,9 volumes appear, for every two of gas decomposed; and of these, two, are oxygen and the rest chlorine. A little chlorine is absorbed, however, by the mercury, and it is reasonable, Sir H. Davy thinks, to conclude, that the deep yellow gas is, in reality, composed of two in volume of oxygen, and one of chlorine, condensed into two volumes.* If this be correct, the gas will consist, by weight, of one atom of chlorine 36, and four atoms of oxygen 32, and its atom will weigh 68.

Composition.

Decomposed by Phosphorus.

293. It is decomposed, at common temperatures, by no combustible body, except phosphorus, which occasions an explosion when introduced into it, and burns, in the liberated gases, with great brilliancy.

Its solution in water.

294. Its saturated solution in water, which contains seven volumes of gas, is of a deep yellow colour. It does not taste sour, but extremely astringent and corroding; and it leaves on the tongue a disagreeable and lasting impression. The solution may be kept in the dark unchanged. but, when exposed to the sun's rays, it is decomposed, and chlorine and chloric acid are obtained. H. 1. 218.

Chloric acid.

295. *Chloric Acid.*—A third compound of chlorine and oxygen was pointed out by Mr Chevenix, some time before it was obtained in a separate form, as existing in the class of salts called hyper-oxymuriates. For the method of exhibiting it in a distinct state, we are indebted to Vauquelin† and Gay-Lussac.‡ The following is the process: To a solution of pure chlorate of barytes, (the mode of preparing which will be hereafter described), add by degrees dilute sulphuric acid, as long as it occasions any precipitation. This separates the barytes, and leaves the chloric acid combined with water only. It is important to add no more sulphuric acid than is barely sufficient; for the slightest excess renders the chloric acid impure. If the right quantity has been used, the liquid obtained should remain perfectly transparent, when, taking two separate portions of it, we add to the one dilute sulphuric acid, and to the other, chlorate of barytes. If either of these agents occasions a precipitate,

Method of obtaining it.

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* The gas called Euchlorine by Sir H. Davy appears to be a mixture of chlorine with this gas, and not a definite compound of two volumes of chlorine and one volume of oxygen. Should it however upon more accurate inquiry prove a definite combination, it might be termed *chlorous oxide*, and the above compound would then be *chloric oxide*. Brande.

† Ann. de Chim. xcv. 102. ‡ Ibid. xci. 111.

we must add it by degrees till the effect ceases. The clear liquid is then to be decanted by a syphon, and reserved for use. It is a solution of chloric acid in water; and has the following properties:

Properties.

296. It is colourless, its taste is acid and astringent; and its smell, when concentrated and a little heated, is moderately pungent. It reddens the infusion of litmus. Paper stained with litmus, though it does not immediately lose its colour, yet is deprived of it in a day or two if left in the liquid; or more rapidly if taken out of the liquid and exposed to the air, in consequence of the solution becoming more concentrated. It does not precipitate either silver, mercury, or lead, from their solution in nitric acid. It is volatilized by heat, but not without a partial decomposition into chlorine and oxygen. Hence it afterwards precipitates the nitrate of silver.

Decomposed by muriatic acid, &c.

297. Muriatic acid decomposes it, and both acids, if mixed in just proportion, are changed entirely into chlorine.

298. Chloric acid is decomposed, also, by sulphuretted hydrogen and by sulphurous acid. In the first case, chlorine and sulphur are separated, and water is formed. In the second, sulphuric acid is formed, and chlorine set at liberty. None of the acids, which are saturated with oxygen, have any action on chloric acid.

299. All the metals that are capable of decomposing water, decompose also the chloric acid, and afford compounds of chlorine with a metallic oxide.

Composition.

300. According to the experiments of Vauquelin, chloric acid is composed of

Chlorine	35	100	54
Oxygen	65	185	100
	100		

This determination differs materially from that of Gay-Lussac, according to whom 32,304 oxygen convert 28,924 chlorine into chloric acid, and hence it should be composed of

Chlorine	47.3	100	90
Oxygen	52.7	110	100
	100.		

The result of Gay-Lussac is by much the more probable of the two, and would make the chloric acid consist of 1 atom of chlorine 36+5 atoms of oxygen 40=76; while Vauquelin's numbers would indicate no less than 8 atoms of oxygen.

301. It is proper, however, to add, that the existence of a simple combination of chlorine and oxygen has been denied by Sir H. Davy, who considers the liquid, obtained by Gay-Lussac, as constituted of two proportions (atoms) of hydrogen, one of chlorine, and six of oxygen. To this, the latter has

replied, that the hydrogen is not an element of the acid itself, but of water, with which the acid is united, as is the case with liquid sulphuric and nitric acids.* H. 1. 220.

Perchloric acid.

302. *Per-chloric or Oxychloric acid.*—In obtaining peroxide of chlorine by Sir H. Davy's or by Count Stadion's process, a peculiar salt is formed, which was first noticed by the latter philosopher. It is mixed with bisulphate of potash, which may be separated by a second crystallization, and the peculiar salt then appears in octoedral crystals. It requires 55 times its weight of water at 60° for solution, but dissolves freely in boiling water. In alcohol, it is quite insoluble. When distilled with an equal weight of sulphuric acid, at a temperature of 280° Fahrenheit it is decomposed : and an acid (of whose properties, however, we have not a distinct account) may be distilled over. When the salt is distilled alone at 412°, it is converted into chloride of potassium (dry muriate of potash) and oxygen gas, in the following proportions. One hundred parts by weight afford

Properties.

Composition.

Chloride of Potassium . . . 54,08 containing { 28,49 potassium, 25,59 chlorine }
Oxygen 45,92

100.

303. Hence it appears, that 25,59 chlorine are united with 45,92 oxygen, which is nearly in the proportion of 36 chlorine to 64 oxygen. Per-chloric acid will therefore consist of one atom of chlorine = 36, united with 8 atoms of oxygen = 64; and the weight of its atom will be 100. H. 1. 222.†

304. According to the experiments of Sir H. Davy and Count Stadion chlorine combines with no fewer than five proportions of oxygen, forming three oxides and two acids. The composition of these different compounds, which, with the exception of chloric acid, have been analyzed only by Davy and Von Stadion, is as follows :

			Atomic weight.	
			Oxygen = 1	Hydrogen = 1
1. Protoxide of chlorine	1 atom	+ 1 atom	5,5	44
2. Tritoxide “ . .	1	+ 3	7,5	60
3. Quadroxide “ . .	1	+ 4	8,5	68
4. Chloric acid . . .	1	+ 5	9,5	76
5. Percloric acid . . .	1	+ 7	11,5	92

Thomson's *First Principles,* Vol. 1, p. 84.

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* See Ann. de Chim. et de Phys. Vol. 1.—Quartr. Jour. I. 286.

† In Mr Brande's tables the weight of the atom of this acid is 92, this is on the supposition that it contains but 7 atoms of oxygen = 56 + 1 chlorine = 36.

SECTION IV. *Of Iodine.*

Discovery of Iodine.

305. Iodine was discovered accidentally by M. Courtois, a manufacturer of saltpetre at Paris, in 1812. Its properties have been fully investigated by Vauquelin. (*Annales de Chimie. tom.* xc.) Gay-Lussac (*ib.* xc.) and Davy (*Phil. Trans.* 1814.)

In the process for procuring soda from the ashes of sea weeds, M. Courtois found that his metallic vessels were much corroded, and in searching for the cause, he made the discovery of Iodine.

Process for obtaining Iodine.

306. Iodine is procured by the following process. Lixiviate* powdered *kelp* with cold water. Evaporate the lixivium till a pellicle forms, and set aside to crystallize. Evaporate the mother liquor to dryness, and pour upon the mass half its weight of sulphuric acid. Apply a gentle heat to this mixture in the flask *a* of the *alembic* shown in fig. 83, of which the head or capital *b*, has a tube issuing from it, and descending into the receiver *c*. Fumes of a violet colour arise and condense in the form of opaque crystals, having a metallic lustre, which are to be washed out of the head of the alembic with a small quantity of water, and quickly dried upon bibulous paper.

Dr Ure's process.

307. Iodine may likewise be obtained from the "*black ash*" of the soap-makers, the residuum of the alkaline matter used in the manufacturing of hard soaps with kelp. Dr Ure has made many experiments with this substance, from which he obtains the Iodine by the following process.

The liquid is heated to about 230° F. and poured into a large stone ware basin of which it should fill about one half; sulphuric acid, previously diluted with its own bulk of water, is added till the liquor is saturated. On cooling the mixture a large quantity of saline crystals are found adhering to the sides and bottom of the vessel † The cold liquid is filtered through a woollen cloth. To every 12 oz .apothecaries' measure 1000 grains of black oxide of manganese, in powder, are added. This mixture is put into a matrass, fig. 84, with a wide neck, over which a glass globe is inverted, and heat is applied with a charcoal chauffer.‡ Iodine now sublimes very copiously, and is condensed in the upper vessel. As soon as it becomes warm, another is to be put in its place; and thus the two may be applied in rotation, as long as the violet vapour rises. By this treatment from 80 to 100 grains of iodine may be obtained. It is removed from the globes as in the other process. The best subliming temperature is 232° F. U. 513.

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* When water is poured upon certain bodies for the purpose of extracting their saline ingredients, the process is termed *lixiviation*, and the solution obtained, a *lixivium*.

† These are chiefly sulphate of soda, a little sulphate of potash, and a few oblong rhomboidal plates of hydriodate of soda. Sulphur is mixed with these crystals.

‡ The less diffusive flame of a lamp is apt to crack the bottom of the matrass, particularly if a large quantity of materials be employed. To prevent the heat from acting on the receiver, a thin disc of wood, having a round hole in its centre, is placed over the shoulder of the matrass.

308. Iodine is a solid at the ordinary temperature of the atmosphere. It is often in scales resembling those of micaceous iron ore; sometimes in large and brilliant rhomboidal plates; and occasionally in elongated octoëdrons.* Its colour is bluish black; its lustre metallic; it is soft and friable, and a non-conductor of electricity. It produces a yellow stain upon the skin. Its smell resembles that of diluted chlorine. Its taste is acrid. Its specific gravity is 4,946. Properties.

Iodine is fusible at 225° F. and, under the ordinary pressure of the atmosphere, is volatilized at a temperature somewhere near 350°, forming a gas 125 times denser than hydrogen, which last number represents the weight of its atom. According to Gay-Lussac, the specific gravity of its vapour, compared with air is 8,678. Hence 100 cubic inches should weigh 269 grains.† The volatilization of iodine at the heat of boiling water, which happens when it is distilled with that fluid, depends on its affinity for aqueous vapour. H. 1. 223.

309. The colour of the vapour of iodine is a beautiful violet, and hence its name, (from ἰώδης, violaceus.)

This may be exhibited by introducing a few scales of iodine into a glass matrass, and heating it over a spirit lamp. Exp.

310. Like chlorine and oxygen, iodine is electro-negative; and therefore attracted by the positive surface of the Voltaic pile. It renders vegetable colours yellow. It is very sparingly soluble in water, that liquid not holding more than $\frac{1}{7000}$ its weight in solution. The colour of the solution is yellow. It is much more soluble in spirit of wine, and in ether.

311. Iodine combines with oxygen and chlorine, and gives rise to acid compounds, which have been called *Iodic* or *oxiodic*, *iodous*, and *chloriodic* acids. Combinations with oxygen.

312. *Iodic acid*, (Davy, *Phil. Trans.* 1815.) This compound of oxygen and iodine cannot be obtained directly, for those bodies exert no mutual action. It is procured by acting upon oxide of chlorine by iodine. For this purpose the iodine may be introduced into a small flask, and the oxide of chlorine disengaged upon it, from a proper mixture of chlorate of potassa and sulphuric acid with the precautions above pointed out (291), or 100 grains of chlorate of potassa may be introduced into a small retort, with 400 grains of liquid muriatic acid of the sp. gr. 1,105: annex to the retort a small globular receiver, having a bent tube issuing from it, and passing to the bottom of a small flask, containing about 50 grains of iodine; carefully apply the heat of a lamp to the retort, by which oxide of chlorine will be disengaged, and which will be decomposed and absorbed by the iodine. A compound is then formed, which consists of chloriodic and oxiodic acids. The former is Iodic acid. Method of procuring.

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* Dr Wollaston has described the form of its crystal in the Annals of Philosophy, V. 237.

† The specific gravity of iodine vapour, according to the late experiments of Dr Thomson, is 8,6111, air = 1. 100 cubic inches weigh 262,6308 grains. Its atomic weight, oxygen=1 is 15,5.

separable by a gentle heat, the latter remains as a white, semitransparent, sour, and inodorous body, very soluble in water.

Decomposition.

313. When decomposed by heat in a pneumatic apparatus, it is resolved into oxygen gas and pure iodine; and it is therefore termed by Sir H. Davy *oxyiodine,* and by Gay-Lussac *acide iodique anhydre.**

	Hyd.=1	Oxy.=1
It consists of 5 atoms of oxygen	=40	5
1 atom of iodine	=125	15,5
and the weight of its atom is	165	20,5 T.

Solution of iodic acid.

314. Anhydrous iodic acid is very soluble in water, and is slightly deliquescent. Its solution, called by Gay-Lussac *acide iodique,* first reddens, and then destroys vegetable blues, and reduces other vegetable colours, to a dull yellow. When evaporated sufficiently, it becomes a thick pasty substance, and at length, by a cautiously regulated heat, yields the anhydrous acid unaltered.

Properties.

315. When heated in contact with inflammable bodies, or with the more combustible metals, detonations are produced. Its solution in water rapidly corrodes all the metals, and even acts on gold and platinum, but especially on the first.

Produces iodates.

316. When its solution is poured into solutions of alkalis, or alkaline earths, or when made to act on their carbonates, triple compounds are formed of oxygen, iodine, and the metallic bases, called by Sir H. Davy *oxyiodes;* and by Gay-Lussac, perhaps more properly, *iodates.*

Combines with acids.

317. Iodic acid enters into combination with all those fluid or solid acids, which it does not decompose. All its acid combinations redden vegetable blues, dissolve gold and platinum; and when added to alkalis or earths, afford common neutral salts, and their respective iodates. H. 1. 225.

Iodous acid.

318. *Iodous acid.* M. Sementini of Naples, has lately published an account of a combination of iodine and oxygen, (See *Boston Jour. of Philos.* ii. 292) containing less of the latter than iodic acid.

Method of procuring iodous acid.

319. It is obtained in the following manner:—equal parts of chlorate of potassa and iodine are to be triturated together, in a glass or porcelain mortar, until they form a very fine pulverulent yellow mass, in which the metallic aspect of the iodine has entirely disappeared. If there be excess of iodine, the mixture will have a lead colour. This mixture is to be put into a retort, the neck being preserved clean, and a receiver is to be attached with a tube passing to the pneumatic trough. Heat is then to be applied, and for this purpose a spirit-lamp will be found sufficient; at first a few violet vapours rise, but as soon as the chlorate begins to lose oxygen dense yellow fumes will

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* The term *anhydrous,* which will be often used, is derived from a Greek word signifying *without water.*

appear, which will be condensed in the neck of the retort into a yellow liquid, and run in drops into the receiver; oxygen gas will at the same time come over. When the vapour ceases to rise, the process is finished, and the iodous acid obtained will have the following properties.

Properties.

320. Its colour is yellow; its taste acid and astringent, and leaving a burning sensation on the tongue. It is of an oily consistency, and flows with difficulty. It is heavier than water, sinking in it. It has a particular odour, disagreeable, and something resembling that of euchlorine. It permanently reddens vegetable blues, but does not destroy them. It is very soluble in water and alcohol, producing amber-coloured solutions. It evaporates slowly, and entirely in the air. At 112° F. it volatilizes rapidly, forming the dense vapour before mentioned. It is decomposed by sulphur, disengaging a little heat, and liberating violet vapours. Carbon has no action on it at any temperature; solution of sulphurous acid decomposes it as well as iodic acid, precipitating the iodine as a brown powder. It is characterized by the manner in which potassium and phosphorus act on it; the instant they touch it they inflame; the potassium producing a white flame and dense vapours, but little or no liberation of iodine; and the phosphorus, with a noise as of ebullition, violet vapours appearing at the same time.

Its composition has not been experimentally ascertained.

Chloriodic acid.

321. *Iodine and Chlorine.* **Iodine absorbs less than one third its weight of chlorine, and forms a peculiar acid which may be called** *chloriodic acid,* and its compounds *chloriodates.* This acid is easily obtained by the direct action of chlorine upon iodine. They unite and form crystals of a deep orange colour, deliquescent, and easily fusible and soluble.*

322. According to Gay-Lussac, indeed, two compounds result, the one of a fine orange-yellow colour, containing the largest proportion of chlorine, the other orange-red. Both are solid and crystalline; deliquiate when exposed to the air; are fusible into an orange liquid; and give an orange-coloured gas. The watery solution takes more iodine, and acquires a deep colour; but if agitated with chlorine, it is deprived of colour, and when poured, in that state, into solution of potash, the deflagrating salt is precipitated. From liquid ammonia, the colourless liquid precipitates a white detonating compound; but the coloured solution throws down the darker compound, which detonates on the slightest touch, and is indeed, identical with that procured by the direct action of iodine on ammonia, to be hereafter described.

Precipitates metallic salts.

323. Chloriodic acid (or *chlorure* of *iodine,* as it is called by Gay-Lussac) precipitates the salts of iron, lead, tin and copper; probably in the state of iodates.

Nature of iodine.

324. *Nature of Iodine.* Iodine, from all that we yet know respecting it, is to be considered as a simple or elementary

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* According to Davy, (*Phil. Trans.* 1814,) this compound contains 125 iodine, 36 chlorine.

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body, having a very striking analogy with chlorine, which it resembles, 1stly, in forming one acid by uniting with hydrogen, and a different acid with oxygen; 2dly, in its effects on vegetable colours; 3dly, in its affording, with the fixed alkalies, salts which nearly approach in characters to chlorates; and 4thly, in its electrical habitudes. Its discovery, indeed, lends strong support to that theory, which considers chlorine as a simple body, and muriatic acid as a compound of chlorine and hydrogen. In the property of forming an acid, whether it be united with hydrogen, or with oxygen, iodine bears, also, an analogy to sulphur; and it is remarked by Gay-Lussac of the combinations of chlorine, iodine, and sulphur, with the elements of water, that while the acids, which they respectively form with oxygen, have their elements strongly condensed, those formed with hydrogen have their elements very feebly united. Sulphur has the strongest affinity for oxygen, then iodine, and lastly chlorine. But for hydrogen, chlorine has a stronger attraction than iodine, and iodine than sulphur; whence it appears that the affinity of each of those bodies for oxygen is inversely proportionate to its affinity for hydrogen.

Sources of iodine in nature.

325. The source of iodine in nature has been investigated with much ability by M. Gaultier de Claubry.[*] His first experiments were directed to the analysis of the several varieties of Fucus, the combustion of which furnishes the soda of seaweeds. Before these vegetables are destroyed by combustion, he ascertained that iodine exists in them in the state of hydriodate of potash; and that calcination only destroys the vegetable matters, with which it is combined. As the hydriodate of potash is a deliquescent salt, it remains in the mother liquor, after separating the carbonate of soda, and most of the other salts, by crystallization. In the course of these experiments, M. de Claubry found that starch is one of the most delicate tests of the presence of iodine, and if added to any liquid containing it, with a few drops of sulphuric acid, iodine is indicated by a blue colour of greater or less intensity.[†] In this way he detected iodine in the decoction of several varieties of Fucus; but he was unable to discover the slightest trace of it

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[*] Ann. de Chim. xciii. 75, 118.

[†] Notwithstanding the delicacy of the test for the presence of iodine afforded by the use of starch, its value is considerably diminished by the facility with which various substances interfere with its action; and this is especially the case when any of those bodies, which either alone or with water, yield hydrogen are present; the iodine becomes hydriodic acid, and the blue colour either disappears, or is not formed. Sulphurous acid and sulphuretted hydrogen, substances almost constantly produced by the incineration of organized bodies, which contain earthy or alkaline sulphates, are especially capable of producing this effect.

Among the various means of obviating this inconvenience is the use of chlorine. M. Baland has been led to apply it in the following manner:—after mixing the liquid containing the iodine with the starch and the sulphuric acid, a small quantity of aqueous solution of chlorine is to be added which from its lightness may be made not to mix with the mixture, but float on the surface; at the place, however, where they touch, a blue zone will be developed where the two solutions are in contact, but if the whole be mixed, it will entirely disappear, if the chlorine be in excess.—*Ann. de Chim.* xxxviii 179.

in sea-water. The Fucus Saccharinus yielded it most abundantly; and in order to obtain it by the cheapest and easiest process, he recommends that we should submit this fucus, dried and reduced to powder, to distillation with sulphuric acid. H. 1. 227. Iodine has also been detected in several mineral waters, and in various marine animals and vegetables.

CHAPTER III.

OF ELECTRO-POSITIVE SUBSTANCES.

326. The bodies belonging to this class, when separated from their combinations with the substances described in the last chapter, by Voltaic electricity, are attracted by the negative surface. With very few exceptions, they combine with oxygen, chlorine and iodine, and of the compounds formed, one or more are acids, hence they may also be termed *simple acidifiable* substances. They are six in number:

1. Hydrogen.
2. Nitrogen.
3. Sulphur.
4. Phosphorus.
5. Carbon.
6. Boron.

Section I. *Hydrogen.*

327. Hydrogen was first duly examined by Mr Cavendish. (*Phil. Trans.* Vol. lvi). The most simple form in which it has hitherto been obtained, is in that of a gas, that is, in a state of union with caloric, and perhaps with electricity and light. From this combination we are not able to separate it, except by availing ourselves of the affinity of some other substance, in which case the hydrogen separates from the caloric, and forms with the body which has been added, a new combination. Of its nature we know but little, but as it has not yet been resolved into any more simple form, it is still arranged among elementary bodies.

Method of procuring hydrogen gas.

328. To procure hydrogen gas, let sulphuric acid, previously diluted with five or six times its weight of water, be poured on iron filings, or on small iron nails; or (what is still better) pour sulphuric acid, diluted with eight parts of water, on zinc, granulated by pouring it melted into cold water, and contained in a gas bottle, fig. 65, or small retort. An effervescence will

ensue, and the escaping gas may be collected in the usual manner over water.

Inflammable air lamp.

329. An ingenious apparatus for obtaining it instantaneously, in a laboratory, is described by Gay-Lussac, in the 5th vol. of Ann. de Chim. et Phys. p. 300. It consists of a three-necked glass bottle, fig. 85, one of whose openings has a stopper, from which is suspended a small cylinder of zinc *a*. To the opposite aperture is fixed a bent brass tube furnished with a stop-cock, on which may be screwed either a small jet for burning the gas, or a tube to conduct it wherever it may be required. The upper vessel is of glass, and ground to fit the middle neck, its pipe reaching within a small distance of the bottom of the bottle. To use the apparatus, the lower vessel is filled with sulphuric acid properly diluted, and the zinc cylinder is then introduced, the stopper being closed to which it is affixed, and the cover of the upper vessel removed. The gas, which is generated, drives the diluted acid into the upper vessel, and the further production of it ceases, when the zinc is completely uncovered. We have then the bottle filled with gas; and can at any time expel it by opening the cock, and allowing the atmosphere to press on the surface of the liquid in the globular vessel.

Impure, as commonly obtained.

330. Hydrogen gas, thus obtained, is not, however, to be considered as absolutely pure.* An observation of Mr Cuthbertson long ago rendered it probable, that, when disengaged by zinc, it contains a portion of that metal; and, when generated by means of iron, it is apt to contain a little carburetted hydrogen.

Properties.

331. Hydrogen is an aëriform fluid not absorbable by water. It has no taste, a slightly disagreeable smell, and may be respired for a short time, though it is instantly fatal to small animals.

332. It is the lightest body known, and is therefore conveniently assumed as unity in speaking of the specific gravity of gases, as well as in referring to the proportions in which bodies combine. 100 cubic inches weigh 2,1180 grains. Its specific gravity is 0,0694 when common air is taken as 1,00. If oxygen is taken as unity, the specific gravity of hydrogen will be 0,0625, and 0,125 will represent its atomic weight.

Exp.

333. The levity of hydrogen may be proved by experiment. Let a jar filled with this gas stand, for a few seconds, with its open mouth upwards. On letting down a candle, the gas will be found to have escaped.

Exp.

Place another jar of the gas inverted, or with its mouth downwards. The gas will now be found to remain a short time in the jar, being prevented from escaping upwards by the bottom and sides of the vessel.

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* In order to purify the zinc Dr Thomson exposes it to a white heat in a stone ware retort, luted to a receiver nearly filled with water. At this temperature, the zinc is sublimed and freed from all its impurities, except a trace of cadmium too minute to occasion any sensible error. The zinc thus distilled over is melted to a crucible and poured upon the surface of a clean smooth sandstone, upon which it forms a thin sheet which can be easily broken into small pieces. T. *First prin.* 1. 52.

334. Hydrogen, in consequence of its extreme lightness, is employed for filling air-balloons.

Exp.

Fill, with hydrogen gas, a bladder furnished with a stop-cock, fig. 71; and adapt to this a common tobacco-pipe. Dip the bowl of the pipe into a lather of soap, and, turning the cock, blow up the lather into bubbles. These bubbles, instead of falling to the ground, like those commonly blown by children, will rise rapidly into the air.

Exp.

The experiment may be varied by filling the bladder with a mixture of two parts of hydrogen gas and one of oxygen gas. Bubbles, blown with this mixture, take fire on the approach of a lighted candle, and detonate with a loud report. It is proper, however, not to set them on fire, till they are completely detached from the bowl of the pipe; otherwise the contents of the bladder will be exploded, with considerable danger to the operator.

Inflammable.

335. Hydrogen is inflammable, and when pure burns with a lambent blue flame at the surface in contact with the air.

Exp.

Fill a small jar with the gas and holding it with the mouth downwards, bring the gas into contact with the flame of a candle.

Exp.

Fill with this gas a bladder which is furnished with a stop-cock, and with a small pipe, of diameter less than that of a common tobacco-pipe. Press the air out through the pipe, and on presenting a lighted candle, the stream will take fire, and continue to burn with a pale and feeble flame.

Exp.

Persons, who are provided with the jars represented fig. 69, *a*, may screw to the cock a brass pipe with a small aperture. On pressing the jar, filled with hydrogen gas, into the water, and opening the cock, the gas will be forced out in a stream, which may be set on fire. On this principle are founded the artificial fireworks without smell or smoke. They consist of pipes, having variously sized apertures, some of which have a rotatory motion. H. 1. 233.

Dœbereiner's hydrogen lamp.

336. It has been found by Prof. Dœbereiner, that when a stream of hydrogen is directed upon spongy platinum (obtained by adding muriate of ammonia to a solution of platinum in nitro-muriatic acid) the platinum soon becomes red hot, and the hydrogen is inflamed. This discovery has led to various modifications of the inflammable air lamp (329). A very convenient and ornamental form of which is represented in fig. 86. It is composed of two glass vessels fitted to each other by grinding, as in the apparatus of Gay-Lussac. The tube *a*, of the upper vessel is encompassed by a cylinder of zinc, which is supported by a ring of cork on the lower part of the tube. The platinum sponge is contained in a small brass box *b*, attached to a brass wire passing through a collar of leather and which can be placed at any distance from the jet, *c* When a light is required the cock *d* is turned, and the pressure of the acid liquor in the upper vessel expels the hydrogen, as in the apparatus already described.

Detonates with air.

337. If mixed with common air, hydrogen burns rapidly with detonation.

Into a strong phial, capable of holding about 6 ounces of water, introduce one part of hydrogen and three parts of common air. On applying a lighted candle or a red hot wire, the mixture will explode. This experiment may be performed by means of an apparatus called the inflammable air pistol, fig. 87.

Pl. 2.

Inflammable air pistol.

This instrument consists of a cylinder of brass, about three-fourths of an inch diameter, and six inches long, in the form of a small cannon or pistol-barrel, properly mounted, and having a wire, *a*, passing through a tube of ivory, *b*, and not quite touching the interior of the cylinder, at the part usually occupied by the touch-hole; an electric spark communicated to this wire inflames the mixture of hydrogen and atmospheric air in its interior. It may be charged by previously filling it with dry sand, and emptying it out into a phial of hydrogen, which rises into the gun sufficiently mixed with air; the muzzle may be secured by a cork, which is expelled with much violence and a loud report, upon the inflammation of the gas. It may be also charged, by holding it for a moment over the open jet of the instrument, fig. 85, always taking care that there is a due admixture of atmospheric air, otherwise the electric spark will not inflame it.

Detonates with oxygen.

Exp.

338. If the experiment be repeated with oxygen gas, instead of atmospherical air; changing the proportions, and mixing only one part of the oxygen gas with two of hydrogen, the report will be considerably louder. The bottle should be a very strong one, and should be wrapped round with cloth, to prevent an accident.

and by means of the electric spark.

The same experiment may be made over water, by means of the electric spark. Procure a strong tube, about three quarters of an inch diameter, and 12 inches long, closed at one end, fig. 88. About a quarter or half an inch from the sealed end, let two small holes be drilled, opposite to each other, and into each of these let a brass conductor be cemented, so that the two points may be distant from each other, within the tube, about one eighth of an inch. An apparatus, serving the same purpose, and much more easily constructed, may be formed by hermetically sealing a piece of brass wire, or still better, platina wire, into the end of a glass tube, fig. 88, *c*. With this conductor, an interrupted circuit may be formed, by introducing into the tube a longer wire, one end of which terminates one-tenth of an inch from the upper one, while the other extends beyond the aperture of the tube. (See fig. 85.) Into this tube, standing over water, pass about half a cubic inch of a mixture of hydrogen and oxygen gases; in the proportion of two measures of the former to one of the latter. Hold the tube firmly, and pass an electric spark through the mixed gases. For relieving the shock, which is sometimes considerable on firing, an ingenious contrivance of Sir H. Davy may be employed. (*Philos. Mag-*

ercise, xxxi. 3.) The first effect of the combustion is a sudden and considerable enlargement of volume, which from some experiments of Sir H. Davy (on *Flame*, p. 90) probably amounts to 15 times the original bulk of the mixture. After this the gases if perfectly pure, and in the proper proportion, will be found to have disappeared entirely. H. 1. 235.

Musical tones during the combustion of hydrogen.

339. A current of hydrogen may be inflamed when issuing from a small aperture, and if a tube of 18 or 20 inches in length fig. 97, be held over the flame, a peculiar musical tone is produced. This effect is not peculiar to hydrogen, but is produced by a variety of other flames, and is referable to the succession of explosions produced by the combustion of the gas in the tube. (Faraday, *Journal of Science and the Arts*, Vol. v.)

Does not support combustion,

340. Hydrogen gas, though inflammable itself, extinguishes burning bodies.—Bring an inverted jar, filled with this gas, over the flame of a candle; and suddenly depress the jar, so that the lighted wick may be wholly surrounded by the gas. The candle will immediately be extinguished.

or life.

341. It is fatal to animals.—This may be shown by confining, in the gas, a mouse or other small animal.

Gases have a powerful tendency to mix together.

Exp.

342. The tendency which gaseous fluids have to become completely mixed under all circumstances, and as it were to penetrate each other, is well illustrated where hydrogen is employed. Thus, if two small phials, the one containing oxygen and the other hydrogen, be connected perpendicularly by a long glass tube, of small bore, it will be found, that although the hydrogen be uppermost, and much lighter than the oxygen, it will, in the course of a few hours, have perfectly mixed with the oxygen, and the gases will be found in equal proportions in both phials. Mr Dalton has shown that gases, unlike other fluids, do not remain upon each other without admixture.—*Manchester Memoirs*, Vol. i. New Series.

Dr Hare's blow pipe.

343. The flame of hydrogen is occasionally employed for exciting intense heat; and it has been found when mixed with oxygen and burned as the mixture issues from a small jet, to excite a temperature nearly equal to that of the arc of flame in the Voltaic circuit. A blow pipe upon this construction was first made by Professor Hare of Philadelphia; it consists of a cylindrical vessel of tin, fig. 89, *a*, or what is preferable copper, divided in the middle by two partitions, so as to form two distinct reservoirs, one for oxygen and the other for hydrogen. Into the lower part of each reservoir a tube *b*, is inserted somewhat obliquely, as in the common gas holder. Above the reservoirs is a conical tin funnel *c*, furnished with a stop-cock and connected with a tube which immediately below divides into two, one passing to each reservoir. A tube passes out from each reservoir, which meet in a cone *d* (a section of which is represented at *e*). The gases are thus mingled and are then made to issue through a capillary tube drilled through a

wire of silver and inserted into the cone.* The lower tubes being closed, the apparatus is filled with water, and the gases introduced, as in the usual method of filling a gas holder. The reservoirs being filled, the lower tubes are closed, and water poured into the funnel, on opening the stop-cocks the gases are propelled through the jet. When substances are to be exposed to the action of this instrument, the stop-cock connected with the reservoir of hydrogen should be first opened and the gas may be inflamed; the other stop-cock is then gradually opened, and the oxygen mixing with the hydrogen, an intensely high temperature is obtained.

With this instrument Professors Hare and Silliman have effected the fusion of some of the most refractory substances in nature. (*Amer. Jour. of Science*, Vol. II. p. 281, &c.)

Brooke's blow pipe.

344. The blow pipe invented by Mr Brooke depends for its action on the elasticity of compressed air, and consists of a strong copper box, fig. 90, into which several atmospheres are crowded by means of a condensing syringe. Various expedients have been adopted to render this a safe substitute for the oxyhydrogen blow pipe of Dr Hare. The most effectual of which consists in interposing between the flame and the main reservoir of gases, a cylinder containing a little water or oil, through which, by means of a valve at the bottom, the gases are allowed to pass. The safety of the instrument is increased by the interposition of a bundle of capillary tubes, between the stop-cock and the orifice of the pipe at which the gases are inflamed.

Gurney's blow pipe.

345. In the blow pipe of Mr Gurney the mixed gases are contained in a silk bag, or bladder, fig. 91, *d*, which is supported on a table *l*, *l*, *l*, and the necessary degree of pressure is obtained by weights or by the hand upon a moveable press board *m*, below. The gases are conveyed to the bag by means of a pipe laid into and across the table furnished with a stop-cock *h*, upon which may be screwed the bag *g*, or a tube connected with a gas holder. By this arrangement the apparatus may be kept in action for any length of time. Between the reservoir *d*, and the stop-cock *h*, a valve is placed to prevent the return of the gases when pressure is applied at *m*; *i*, *i*, is a light pasteboard or wood cap which in case of an explosion of the gazometer is thrown into the air, by the force rupturing the strings *k*, *k*, *k*, *k*, which, from its extent of surface and great lightness is arrested by the atmosphere. To the stop-cock *c*, a safety apparatus *b*, is attached, which is filled with water to the height *b*, and the gases pass from the reservoir *d*, through a tube reaching to the bottom of the vessel; the upper part of which is closed by a cork *e*; in case of an explosion of the small quantity of gas above the surface of the water, the cork is thrown up; additional security is obtained by a small chamber *a*, containing layers of wire gauze.†

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* Or the jet may be formed of two concentric cones.

† For a more particular description of this blow pipe, see Gurney's *Lectures*, p. 208.

Union with oxygen gas.

346. *Hydrogen and oxygen.*—When two volumes of hydrogen gas are mixed with one volume of oxygen gas, and the mixture inflamed in a proper apparatus by the electric spark, the gases totally disappear, and the interior of the vessel is covered with drops of pure water, equal in weight to that of the gases consumed.

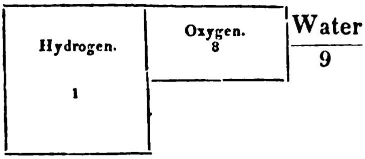
Composition of water.

347. If pure water be exposed to the action of Voltaic electricity, it is resolved into two volumes of hydrogen, disengaged at the negative pole, and one volume of oxygen, disengaged at the positive; so that water is thus proved by synthesis and analysis, to consist of two volumes of hydrogen combined with one volume of oxygen.

348. In determining the proportion of the elements of water, every thing will depend on the precision with which the specific gravities of oxygen and hydrogen gases are ascertained. According to the results of Dr Thomson, oxygen gas is precisely 16 times heavier than hydrogen gas, and according to Berzelius and Dulong a little more than 16 times; but if we take 16 to 1 as the nearest approximation, it will follow, since water consists of two volumes of hydrogen and one of oxygen, that eight parts by weight of oxygen and one of hydrogen constitute water; or according to the last mentioned chemists it consists of

Oxygen	88,9
Hydrogen	11,1
	100. H. 1. 249.

And if water be constituted of one atom of oxygen united with one atom of hydrogen, if we represent the weight of the latter by 1, that of the atom of oxygen will be 8, and $1 + 8 = 9$ is the representative number for water. Or thus



If we assume the weight of oxygen as 1, hydrogen will be 0,125, and the representative number of water 1,125. If we conceive that water is composed of two atoms of hydrogen and one of oxygen, we must double the number for oxygen, in which case we should have 17 for the representative number for water.

But it admits of being proved to be consistent with mechanical principles that the most energetic combination of any two elements is that in which they are united particle to particle. Until therefore the contrary can be established, we may assume, with Mr Dalton, that water is a binary compound of 1 atom of oxygen, and 1 atom of hydrogen. H. 1. 249.

349. The experiments illustrating the composition of water may be divided into synthetic and analytic. Among these the following may be selected.

Exp.

Burn a current of hydrogen under the funnel *a*, fig. 92; by uniting with the oxygen of the atmosphere it will produce aqueous vapour, which passing into the glass cylinder *b*, will condense in drops.

Burns with oxygen gas and forms water.

Fig. 93, represents an apparatus for showing the production of water by burning a current of hydrogen in an atmosphere of oxygen. *a* is a glass cylinder, which after having been exhausted upon an air-pump, is filled with pure oxygen. *b* is a receiver of hydrogen immersed in the vessel of water *c*, by which the gas is compressed, so as to be urged through the capillary opening *f*, when the stop-cocks *d d* are open. *e* is a platinum wire by which the gas may be inflamed by an electric spark. It burns with the production of intense heat, and water is soon collected in drops upon the interior of the cylinder.

The mixture explodes.

Exp.

If two measures of pure hydrogen be mixed with one of pure oxygen, and detonated in the graduated glass tube *a*, fig. 88, standing over water, by an electric spark passed through the platinum wires *b b*, the gases will entirely disappear. If there be any excess of either of the gases, the portion in excess will remain unconsumed.

Exp.

The same experiment may be thus varied, fig. 94, is a very strong glass vessel, capable of holding about half a pint and furnished (besides the proper contrivance at top for taking the electric spark in it) with a brass cap and cock, by means of which it can be screwed to the transfer plate of an air-pump. When exhausted, it may be filled with a mixture of oxygen and hydrogen gases, in the proportion of one measure of the former to two of the latter, and an electric spark may be passed through the mixture. After the explosion, when time has been given to the vessel to cool, a sensible quantity of moisture will have condensed on the inner surface of the vessel, and by repeating the operation frequently, a sufficient quantity of fluid may be collected to show that water is the only product.

Water a compound of the bases of the gases.

350. The water produced in this mode, is not, however, to be considered as a compound of the two gases, but only of their bases, for the light and caloric, which constituted the gases, escape, in considerable part during the combustion. Every gas, it must be remembered, has at least two ingredients; the one, gravitating matter, which, if separated, would probably exist in a solid or liquid form; the other, an extremely subtile fluid, termed caloric and perhaps electricity and light. The compound, water, is therefore said to be composed of hydrogen and oxygen, the *bases* of the gases, and not of hydrogen and oxygen *gases*.

Analysis of water by iron.

351. Water may be decomposed or resolved into its elements by a variety of processes, the most important of which are the following:

Fig. 95, *a*, is a glass retort, into which is introduced a given weight of water; *b b*, a small furnace through which passes the earthen, or iron, tube *c c*, which terminates in the spiral pewter wire, tube *d d*, immersed in water. A given weight of pure iron coiled up, is introduced into the tube *c*, and the whole made red hot; the water in *a* is then made to boil, and the vapour, on coming into contact with the red hot iron, is in part decomposed; the oxygen is retained by the iron, and the hydrogen escaping through the tube *f*, may be collected as usual. Any decomposed portion of water is condensed in the worm-pipe *d*, and drops into the vessel *e*. After this experiment the iron will be found to have increased in weight; and if attention be paid to the quantity of water which has collected in *e*, and to the weight of the hydrogen gas evolved, it will be found that the weight gained by the iron, added to that of the hydrogen, will be equal to the weight of the water which has disappeared. Lavoisier concluded, from an experiment thus conducted, that water consisted of 85 *per cent.* by weight of oxygen, and 15 by weight of hydrogen; that is, that for every 15 grains of hydrogen evolved, 85 grains of oxygen were condensed by the iron.

352. The processes, by which the elementary parts of water are separated from each other, and are both obtained in an aëriform state, as a mixture of hydrogen and oxygen gases, are dependent on the agency of electricity.

By Electricity.

The first of these experiments requires for its performance the aid of a powerful electrical machine. This fact was the discovery of a society of Dutch chemists; and the principal circumstance, in the experiment, is the transmission of electrical shocks through a confined portion of water. The apparatus employed, in this experiment of Messrs. Dieman and Van Troostwyk, is a glass tube, about one-8th of an inch diameter, and 12 inches long, one of the ends of which is sealed hermetically, a gold wire being inserted at this end, and projecting about an inch and a half within the tube. About the distance of five-8ths of an inch from the extremity of this, another wire is to be fixed, which may extend to the open end of the tube. The tube is next to be filled with distilled water, and to be placed inverted in a vessel of the same. When thus disposed, electrical shocks are to be passed between the two ends of the wire, through the water; and, if these shocks be sufficiently strong, bubbles of air will be formed at each explosion, and will ascend till the upper part of the wire is uncovered by the water. As soon as this is effected, the next shock that is passed will set fire to the mixed gases, and the water will rise again in the tube, a very small quantity of gas remaining. Now, as hydrogen and oxygen gases, in a state of admixture, are the only ones that are capable of being inflamed by the electric shock, and as there is nothing in the tube, beside water, that can afford them in this experiment, we may safely infer, that the evolved hydrogen and oxygen gases arise from decomposed water.

By Voltaic electricity. 353. The decomposition of water by galvanic electricity is a process singularly adapted to demonstrate the fact in a simple and elegant manner, since it exhibits both the oxygen and hydrogen in the gaseous form. Fig. 96, represents a section of an apparatus for this purpose. It is a glass vessel containing water, having two wires of platinum, *a a*, passing through its bottom: over these are inverted the tubes *b b*, also filled with water. The wires are rendered positive and negative by connexion with a moderately powerful Voltaic apparatus. Oxygen is evolved at the positive wire, and hydrogen at the negative wire, which gases rise into the tubes, and it is seen that one volume of oxygen, *o*, and two volumes of hydrogen, *h*, are the constant results. If these gases be mixed and detonated, pure water is again formed.

By living vegetables. 354. Another mode of effecting the decomposition of water yet remains to be mentioned, in which, not the hydrogen, but the oxygen is obtained in a gaseous state. This is by the action of living vegetables, either entire, or by means of their leaves only. Fill a clear glass globe with water, and put into it a number of green leaves, from almost any tree or plant. A sprig or two of mint will answer the purpose perfectly well. Invert the glass, or place it, with its mouth downwards, in a vessel of water. Expose the whole apparatus to the direct Exp. light of the sun, which will then fall on the leaves surrounded by water. Bubbles of air will soon begin to form on the leaves, and will increase in size, till at last they rise to the top of the vessel. This process may be carried on as long as the vegetable continues healthy; and the gas, when examined, will prove to be oxygen gas, nearly pure. In this experiment, the hydrogen combines with the plant, to the nourishment and support of which it contributes, while the oxygen is set at liberty. H. 1. 251.

Heterogeneous contents. 355. Water, in its ordinary state, such as spring and river water, is always so far contaminated with foreign substances as to be unfit for many chemical purposes, and frequently, as will be more fully shown hereafter, even for domestic use. Rain-water is much more pure, but it always contains a portion of carbonic acid and of the elements of atmospheric air, besides appreciable traces of vegetable or animal matter; to the latter it owes its property of becoming putrid when kept. The distinction of water into hard and soft has reference to its less or greater purity. The impurities of water are separated by distillation, which process is usually conducted upon the large scale in a copper boiler, fig. 97, placed either in a portable furnace, or set in brickwork, according to its dimensions, to which is annexed a head, *b*, of the same material, or of pewter, connected with a spiral tube or worm, which is immersed in the worm-tub, or refrigerator *d*, its lower end passing out. The water in the worm-tub must always be retained of a low temperature to effect the condensation of the vapour in the spiral tube.

356. *Distilled water*, as commonly prepared, always affords minute traces of foreign matter, especially when subjected to Voltaic decomposition, and can only be considered as perfectly pure when re-distilled at a low temperature in silver vessels.

Properties.

357. Pure water is transparent, and without either colour, taste or smell. In consequence of the facility of obtaining it pure, it is assumed as a standard to which the relative weight of all other bodies may be compared, its specific gravity being called = 1,000, and hence the importance of estimating its weight with precision. At the temperature of 40° it is at its maximum of density, and at that temperature an English cubic foot weighs 437102,4946 grains, (THOMSON's *System*, Vol. ii. p. 18.) or 999,0914161 ounces avoirdupois, and the cubic inch 252,953 grains.

Standard of specific gravity.

Ice.

358. At the temperature of 32° water congeals into ice, which, if slowly formed, produces needles crossing each other at angles of 60° and 120°. The specific gravity of ice is 0,94. Exposed to the air, ice loses considerably in weight by evaporation.

359. If water be exposed to heat in open vessels it boils, or is converted into steam, at 212°, the barometer being at 30 inches; but the boiling point of water varies considerably with the pressure (137.) The specific gravity of air being considered as=1; that of steam is 0,625. At mean pressure, and at the temperature of 212°, the bulk of steam is 1700 times greater than that of water.

Boiling point.

360. Water is susceptible of compression, as was originally shown by Canton, and more lately by Mr Perkins, who has estimated, in an ingenious series of experiments, the rate of its compression. (*Phil. Trans.* 1820.) If submitted to very sudden compression, water becomes luminous, as has been shown by M. Desaignes.—THENARD, *Traité de Chimie*, i. 432.

Compressible.

361. Water enters into combination with a variety of substances, and is retained with various degrees of force: where it contributes to the regular form and transparency of crystallized bodies, it is termed *water of crystallization* (17). In other cases the compounds which water forms with substances are called *hydrates*, as with many of the metallic oxides; in both cases it may be considered as one of the constituents of the bodies, for it exists in them in a definite proportion.

Hydrates.

Water contains air.

362. Water, which has been exposed to the atmosphere, always contains a portion of air, as may be proved by boiling it, or by exposing it under the exhausted receiver of the air-pump. To separate the air, the water must be boiled for about two hours. It absorbs oxygen gas in preference to atmospheric air or nitrogen, and when the air is expelled by boiling, the last portions contain more oxygen than those first given off.—HUMBOLDT and GAY-LUSSAC, *Journal de Physique*, 1805.

363. M. Thenard has shown that water may be united to a considerable excess of oxygen by means of peroxide of barium.

Unites to an excess of oxygen.

(*Quarterly Journal*, Vol. viii. p. 114.) The specific gravity of oxygenated water is about 1,45. It acts as a caustic upon the skin; detonates violently when dropped upon dry oxide of silver, or upon most of the metals finely divided. This singular compound may be termed *peroxide of hydrogen:* its properties, and the process for obtaining it, which is complex and circuitous, have been fully detailed by its discoverer, and will be adverted to under the article *Peroxide of Barium.*

Absorption of gases by water.

364. Every gas is absorbed by water, which has been deprived of all or the greatest part of its air by long boiling. The quantity, however, which water is capable of absorbing, varies considerably with respect to the different gases. Those gases, of which only a small proportion is absorbed, require violent and long continued agitation in contact with water. H. 1. 253. In the common process of manufacturing soda water a large quantity of carbonic acid gas is absorbed by the water, and an additional portion is mechanically united with it by powerful compression.

For the quantity of different gases which water is capable of absorbing, see *Tables.*

Hydrogen assumed as unity.

365. As hydrogen is the lightest known substance, it is assumed, as already remarked (70), by many chemists as *unity*, in reference to the representative numbers of other bodies. The principle of numeric representation, or of equivalent or proportional numbers, has been adverted to (69) and the following will be the representative numbers of some of the bodies described in the foregoing sections, the number for oxygen being deduced from the composition of water (348), and of chlorine and iodine from the muriatic and hydriodic acids.

Undecompounded Substances.	Proportional numbers.
Hydrogen	1
Oxygen	8
Chlorine	36
Iodine	125

Compounds.	Component Parts.		Representative Number.
Water	1 proportional of hydrogen 1 ditto oxygen	= 1 = 8	9.
Peroxide of chlorine	4 proportionals of oxygen 1 ditto chlorine	= 32 = 36	68.
Chloric acid	5 proportionals of oxygen 1 ditto chlorine	= 40 = 36	76.
Perchloric acid	8 proportionals of oxygen 1 ditto chlorine	= 64 = 36	100.
Oxiodic acid	5 proportionals of oxygen 1 ditto iodine	= 40 = 125	165.
Chloriodic ac	1 proportional of chlorine 1 ditto iodine	= 36 = 125	161.

Muriatic acid gas.

366. *Hydrogen and Chlorine.*—When equal volumes of these gases are mixed and exposed to light, they combine and produce a sour compound commonly called *muriatic acid gas;* or in conformity to more modern nomenclature *hydrochloric acid gas.*

367. Chlorine and hydrogen gases act with considerable energy upon each other, and with different phenomena accordingly as the experiment is conducted.

Exp. Explosion of Chlorine and Hydrogen.

If a phial be entirely filled with a mixture of hydrogen and chlorine gases in equal proportions, and a well ground stopper be introduced; no action takes place, provided light be carefully and completely excluded, even by standing some time; but on applying a lighted paper, the gases immediately explode. H. 1. 264.

Exp.

Into a small but strong vessel, guarded from the light, introduce equal volumes of the two gases, and inflame the mixture by the electric spark, no change of volume ensues, and muriatic gas results. The apparatus shown at fig. 94, may be used for this purpose. The vessel should be previously exhausted by the air pump, and if after the detonation the stop-cocks be opened under mercury, none of that fluid will enter, proving that the volume of the gas has not been diminished; but if it be removed to a vessel of water, and left there for a few minutes, the water will be found to have ascended and entirely filled the vessel. Hence a gas must have been generated by the combustion, which, though not absorbable by mercury, is condensable by water.

Exp. Effect of light.

368 If a phial containing the mixed gases be exposed to the sun's rays a detonation will ensue which will probably drive out the stopper. But if this should not happen the stopper may be removed under water, which will ascend and completely fill the phial as in the former experiment.

Exp.

The agency of light may be beautifully shewn by filling a tube about half an inch diameter, and 12 inches long, with the mixed gases, and alternately shading it with an opake cover, and exposing it to the sun's rays. The moment the tube is exposed even to the diffused light of day, a cloudiness will appear within it, and the water will ascend more or less rapidly according to the intensity of the light. The effect even of a passing cloud is distinctly seen in retarding the rapidity of the combination, which is very striking in the full solar light.

369. It had been supposed that the direct beams of the sun were necessary to explode a mixture of chlorine and hydrogen gases; but Professor Silliman has related the accidental explosion of a mixture of the gases, in the quantity that filled a Florence oil flask, not only when no direct solar light fell upon it, but when the diffuse light of day was rendered more feeble than common by a thick snow-storm. (See *Amer. Jour. of Science,* III. 342.) This fact furnishes a caution against mixing the two gases in considerable quantities. H. 1. 266.

Effect of Voltaic Electricity. 370. The intense light issuing from charcoal points connected with a powerful galvanic battery has been found by Mr Brande, as effectual as solar light in acting on hydrogen and chlorine gases; showing a curious analogy between electric and solar light; for ordinary artificial light does not accelerate the combination. BRANDE, *Phil. Trans.* 1820.

Process for obtaining. 371. To obtain muriatic acid gas in sufficient quantity for the exhibition of its properties, the direct combination of chlorine and hydrogen gases is not an eligible process. It may be procured much more conveniently in the following manner.

Let the tubulated gas bottle, fig. 98, *a*, be about one fourth, or one third, filled with well dried chloride of sodium, (common salt) in lumps, not in powder. To this adapt the acid holder, *b*, filled with concentrated sulphuric acid; and let the aperture of the bent pipe *c*, terminate under a jar filled with, and inverted in, quicksilver. Open the communication between the acid and the salt, by turning the cock, *d;* and immediately on the contact of these two bodies, an immense quantity of muriatic acid gas, will be disengaged. A common or tubulated gas bottle, or tubulated retort will answer sufficiently well for procuring the gas. The first portions, that come over, may be allowed to escape under a chimney; because they are contaminated by the admixture of common air present in the bottle. The subsequent portions may be preserved for use. This gas was first obtained pure by Dr Priestley, but its composition was discovered by Scheele, and has since been most ably investigated by Sir H. Davy. H. 268.

Properties. 372. Muriatic acid gas has a very pungent smell; and is sufficiently caustic to blister the skin, when applied to it for some time.

Exp. 373. When brought into contact with common air, it occasions a white cloud. This is owing to its union with the aqueous vapour, which is always present in the atmosphere.

Exp. 374. It extinguishes a lighted candle. Before the flame goes out, the upper part of it assumes a greenish hue, the cause of which has not yet been explained. A white vapour also surrounds the extinguished wick, owing to the combination of water, produced by the combustion of the candle, with the muriatic acid gas.

375. It is heavier than common air. Its specific gravity, air = 1 is 1,28472 and 100 cubic inches weigh 39.1839. Its specific gravity, oxygen = 1, is 1,15625, T; compared with hydrogen it is = 18,5.

Analysis. 376. Muriatic acid may be decomposed by the action of several of the metals. Potassium, for instance, absorbs the chlorine and the hydrogen is evolved; muriatic acid gas thus affords half its volume of hydrogen. As the specific gravity of hydrogen to chlorine is as 1 to 36,0. muriatic acid will consist of 1 hydrogen + 36,0 chlorine and its representative number will be 37,0,

Hydrogen	Chlorine		Muriatic Acid
1,	36,	=	37,0

When oxygen is taken as the unit the atomic weight of muriatic acid is 4,625.

377. The muriatic acid, in its purest form, exists in the state of a gas, which is permanent over mercury only. For exhibiting its properties, therefore, a mercurial apparatus is absolutely necessary.

378. Muriatic acid gas is greedily absorbed by water, which at 40° F. Sir H. Davy found to take up about 480 times its bulk, forming a solution of specific gravity 1,2109. (*Elements*, p. 252.)

Fill a narrow jar, or tube closed at one end, with muriatic acid gas, over mercury, and through the latter pass up a few drops of water, the gas will be rapidly absorbed, and the mercury will rise into the vessel. Exp.

Into a similar vessel filled with the gas introduce a piece of ice; it will be liquefied, almost as rapidly as if touched with a red hot iron, and the gas will be absorbed. Exp.

379. It is in this state of watery combination that muriatic acid is kept for chemical purposes, and all the processes for preparing the liquid acid have for their object the disengagement of muriatic acid gas, and its absorption by water.

Liquid muriatic acid, how obtained.

380. For saturating water with this gas we commonly employ Woulfe's apparatus. The retort being furnished with the bent tube, *a*, fig. 23, and placed in a sand bath. The junctures should be carefully luted, and the acid should be added to the salt in the retort at intervals. The water employed may amount to half the weight of the salt, and may be equally distributed between the bottles. These it is better to surround with cold water, or, still preferably, with ice or snow; because the condensation of the gas evolves considerable heat, which prevents the water from attaining its full impregnation. When the whole of the sulphuric acid has been added, and the gas no longer issues, let a fire be lighted in the furnace, beneath the sand bath, removing the bent tube *a*, and substituting a well ground glass stopper. This will renew the production of gas; and the temperature must be preserved, as long as gas continues to be evolved. At this period it is necessary to keep 7. the luting which connects the retort and receiver, perfectly cool.* Towards the close of the process, a dark-coloured liquid is condensed in the first receiver, consisting of a mixture of sulphuric and muriatic acids. When nothing more comes over, the operation may be suspended, and the liquid in the two re-

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* The clay and sand lute is the best for this juncture.

ceivers must be preserved in bottles with ground stoppers. It consists of liquid muriatic, or hydrochloric acid. H. 269.

Davy's Theory.

381. It was usual, says Sir H. Davy, to explain the phenomena which are observed in these processes, by saying that the sulphuric acid by its superior affinity, aided by heat, expelled the muriatic acid gas from the salt and united with its soda. But as neither muriatic acid nor soda exists in common salt (it being a compound of chlorine and sodium) we must modify the explanation. The water of the sulphuric acid is conceived to be first decomposed, its oxygen unites to the sodium to form soda which is seized on by the sulphuric acid, while the chlorine combines with the hydrogen of the water, and exhales in the form of muriatic acid gas.

Properties.

382. When muriatic acid is thus dissolved in water, it forms the *liquid muriatic acid*, or *spirit of salt*. When pure it is perfectly colourless, but it generally has a yellow hue arising from accidental impurities. Its yellow colour is sometimes owing to muriate of iron: it is instantly destroyed by a few drops of muriate of tin, but this, instead of diminishing, obviously increases the impurity of the acid. When prepared by Woulfe's apparatus, the product in the second bottle is always perfectly pure. It sometimes contains sulphuric acid, which may be discovered by muriate of baryta occasioning a white precipitate, the acid may be purified by redistillation from a fresh portion of common salt.

383. The specific gravity of the acid of commerce is generally about 1,156; but when obtained by means of Woulfe's apparatus, and especially when the bottles are surrounded by ice or snow, it approaches 1,500.*

384. Liquid muriatic acid emits white suffocating fumes, consisting of muriatic acid gas, which become visible by contact with the moisture of the air (373). When heated in a retort, the gas is disengaged, and may be collected over mercury. It is not decomposed by the contact of charcoal, or other combustible bodies. When diluted with water, an elevation of temperature is produced, less remarkable, however, than that occasioned by diluting sulphuric acid (42); and when the mixture has cooled to its former temperature, a diminution of volume is found to have ensued.

Combines with alkalies.

385. Muriatic acid combines readily with alkalies, and with most of the earths, both in their pure and carbonated state. It is specifically heavier than water. H. 1. 272.

Decomposed by substances containing oxygen.

386. When liquid muriatic acid is brought into contact with any substance containing oxygen in a state of loose combination, the hydrogen of the acid unites with the oxygen, and forms water, while the chlorine is liberated in a gaseous state. It is in this way that chlorine is procured for the purposes of chemistry and the arts; but instead of liquid muriatic acid it

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* For the correspondence between its specific gravity and the quantity of real acid which it contains, see *Tables*.

is usual to substitute materials capable of furnishing the acid gas as already described.

Nature of chlorine and muriatic acid.

387. Concerning the *nature of chlorine and muriatic acid*, the opinions of chemists have undergone frequent changes. By Scheele, the discoverer of chlorine, muriatic acid was conceived to be compounded of a certain base and an imaginary principle called *phlogiston*, of which it could be deprived by the action of certain bodies. But as it was afterwards found that all bodies which are capable of producing this change in muriatic acid contain oxygen, and that their proportion of oxygen is diminished by the process, it was concluded that what takes place in the action of metallic oxides on muriatic acid is simply the transfer of oxygen from the oxide to the acid, and the gas which resulted was then called *oxymuriatic*, or *oxygenated muriatic acid*. This view of the subject was modified in consequence of the experiments of Sir H. Davy. and he was led to consider the *muriatic acid* as a compound of a certain basis with water, and the *oxymuriatic* as a compound of the same basis with oxygen. It was found, for example, that when a metallic oxide was heated in muriatic acid gas, oxymuriatic acid was obtained, and water appeared in a separate state. It was therefore evident that the acid gas must either have contained water ready formed; or the elements of water; or hydrogen capable of forming water with the oxygen of the oxide.

388. Subsequent experiments led to a different theory, and oxymuriatic acid is now considered by Sir H. Davy, as a simple or undecompounded substance, and muriatic acid as a compound of that simple substance with hydrogen. Thus, according to this view, to convert muriatic acid into chlorine we have only to abstract the hydrogen of the acid; and to convert chlorine into muriatic acid, we have only to supply it with hydrogen (366).

389. The oxymuriatic acid or *chlorine* (as it is now called) is supposed to unite at once with the metals, without requiring, like the sulphuric, nitric and other acids, that the metals should first be in the state of oxides.* H. 1. 275.

Hydriodic acid.

390. *Hydrogen and Iodine* exert a slow action under ordinary circumstances; but when iodine is presented to nascent hydrogen, they readily unite, and produce a gaseous acid, the *hydriodic acid*. It is prepared by the action of moist iodine upon phosphorus, and must be received over mercury; which, however, soon acts upon and decomposes it, so that it should be transferred as speedily as possible into an exhausted vessel.

391. In procuring it, it is convenient to use a small retort or bent tube, into the bulb of which is introduced the iodine, and a small stick of phosphorus placed in the neck above it, which can be shaken down upon the iodine when the beak of the tube

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* For a full account of the opinions which have been maintained in regard to this subject, the reader is referred to the controversy between Drs Murray and J. Davy, in the 34th vol. of Nicholson's Jour.; to Sir H. Davy's paper in the Phil. Trans. for 1818, p. 169; to the 8th vol. of Trans. of the Royal Soc. Edinr.; the Annals of Philosophy, xii. 379 and xiii. 26, 285; and to a paper by Mr R. Phillips in the new series of that work, Vol. i. p. 27, on the action of chlorides on water.

or retort is placed under the inverted jar; a quantity of the gas is instantly and violently generated, and a further portion is obtained on applying the flame of a spirit lamp.

The gas may also be received into a vessel of common air, which it expels by its superior gravity.

Properties. 392. Hydriodic acid is colourless, very sour, and smells like muriatic acid. Its specific gravity was found by calculation to be 4,428; compared with hydrogen its specific gravity is 62,5 to 1; 100 cubic inches weighing 133,6 grs. H. 1. 278.

Dr Thomson makes the specific gravity 4,34027 air = 1, and the weight of 100 cubic inches 132,3785.

393. Hydriodic acid gas is rapidly absorbed by water, the solution is fuming and has the density of 1,7. The solution exposed to a temperature below 260° becomes concentrated by loss of water; at about 260° it boils, and may be distilled. It becomes dark coloured when kept, in consequence of a partial decomposition, and it readily dissolves iodine, becoming of a deep brown colour.

How best prepared. 394. The liquid hydriodic acid is best prepared by passing sulphuretted hydrogen through a mixture of iodine and water; the hydrogen unites with the iodine, and the sulphur is precipitated, and on heating and filtering the liquor, a pure solution of hydriodic acid is obtained, which may be concentrated by evaporation. Till it attains the temperature of 257° water only distils; above this point, the acid itself is volatilized and remains stationary at 262½°, its density being then 1,7. With solutions of lead it gives a fine orange precipitate, with solution of peroxide of mercury, a red one; and with silver, a white precipitate insoluble in ammonia.

395. It is decomposed by Voltaic electricity, iodine appearing at the positive, and hydrogen at the negative pole.

396. It is decomposed by those oxides which hold their oxygen loosely, and combines with the rest, forming neutral salts called *hydriodates*. H. 1. 279.

Composition. 397. That Hydriodic acid gas consists of equal volumes of hydrogen and vapour of iodine is shown by the action of mercury, which by absorbing the iodine, evolves half a volume of hydrogen from one of the gas.

It is instantly decomposed by chlorine, which produces muriatic acid and the blue vapour of iodine is rendered evident. These gases often take fire on mixture.

398. It is composed by weight, according to Gay-Lussac, of 100 iodine and 0,849 hydrogen; but correcting the specific gravity of hydrogen gas to 0,0694 its true composition will be, by weight

Hydrogen	1
Iodine	125
Weight of its atom . . .	126. H.

Oxygen being = 1 the atomic weight would be 15,625. T.

SECTION II. *Nitrogen.*

How obtained.

399. This was first recognised as a distinct aëriform fluid by Dr Rutherford, in 1772. (Thesis. *De Aere Mephitico.*) It may be obtained by heating phosphorus in a confined portion of dry atmospheric air, which consists of nitrogen and oxygen; the phosphorus absorbs the latter, and the former gas remains. After repeated washing it may be considered as pure.

400. It may also be obtained by inverting a jar full of common air over a mixture of equal weights of iron filings and sulphur made into a paste with water. But this process requires much time.

Other processes.

A quicker process, for procuring nitrogen gas, consists in filling a bottle, about one 4th, with the solution of nitrous gas in liquid sulphate of iron, or with liquid sulphuret of lime, and agitating it with the air, which fills the rest of the bottle. During the agitation, the thumb must be firmly placed over the mouth of the bottle; and, when removed, the mouth of the bottle must be immersed in a cup full of the same solution, which will supply the place of the absorbed air. The agitation, and admission of fluid must be renewed, alternately, as long as any absorption takes place.

Nitrogen may be procured from the lean part of flesh meat, (beef for example), which may be put into a gas bottle, along with very dilute nitric acid. By a heat of about 100°, the gas is disengaged, and may be collected over water. Its source has been satisfactorily traced to the animal substance, no part of it proceeding from the nitric acid.

Derivation of azote.

401. This gas is fatal to animal life and was, on this account, named by Lavoisier *Azote* or *Azotic gas*, derived from the Greek privative α and ζωη, *life*. This being but a negative property, has been deemed an improper foundation for its nomenclature; and the term nitrogen has been substituted, because one of the most important properties of its base is, that by union with oxygen it composes nitric acid. H. 1. 281.

Exp. Exp. Pl. 2.

402. Nitrogen is not inflammable; and a lighted taper immersed in it is extinguished. Even phosphorus in a state of active inflammation is instantly extinguished by it. This is best shown by placing the burning phosphorus in a tin cup raised by a stand, fig. 36, over the surface of the water, and quickly inverting over it a jar filled with nitrogen gas.

Exp.

403. When mixed with pure oxygen gas, in the proportion of four parts to one of the latter, it composes a mixture resembling atmospheric air in all its properties. Of this any one may be satisfied, by mixing four parts of azotic gas with one of oxygen gas, and immersing in the mixture, a lighted taper. The taper will burn as in atmospherical air. H.

404. It is not absorbed by water. It is a little lighter than atmospheric air, 100 cubic inches being found by Sir H. Davy

to weigh 30,04 grains, under a pressure of 30 inches, and at the temperature of 55° Fahrenheit. At 60° Fahrenheit, 100 inches weigh, therefore, 29,73 grains. According to Dr Thomson its specific gravity is 0,9722 air = 1; 0,875 oxygen = 1; and 100 cubic inches weigh 29,6527 grains.

Composition of Nitrogen

405. That nitrogen is not an element, but itself a compound, has been long suspected, and various attempts have been made to discover its ingredients. Berzelius from the combination of experiment with much theoretical reasoning, has deduced, that nitrogen is compounded of oxygen and an unknown base, (2 *Ann. Philos.* 284.) This base, however, is purely hypothetical; and has never yet been exhibited in a separate state. Berzelius has proposed for it the name of *nitricum*.

406. When the compounds of nitrogen are submitted to Voltaic decomposition, it is attracted by the negative pole.

General view of the compounds of Nitrogen and Oxygen.

407. *Nitrogen and oxygen.*—When nitrogen and oxygen gases are mingled together, in whatsoever proportions they are employed, no combination ensues. The result is a simple mixture of the two gases, which do not, like inelastic fluids, separate on standing, but remain diffused through each other for an indefinite length of time. When, however, either one or both of these elements is in a condensed state, or deprived of part of that caloric which keeps the gravitating particles of all gases at a distance from each other, they unite and form compounds, distinguished by very striking properties. According to the proportions in which the oxygen and nitrogen exist in these compounds, their qualities undergo a remarkable variation; so that from two elementary bodies, variously united, we have several compounds, totally unlike each other in external qualities, as well as in their chemical relations.

408. In a series of the compounds of nitrogen, founded on their proportion of oxygen, they occupy (excluding atmospherical air from the number) the following order, the last containing the largest proportion of oxygen; nitrous oxide—nitric oxide or nitrous gas—hypo-nitrous acid—nitrous acid or nitrous vapour—and nitric acid. The two first are sparingly soluble in water; but the three last unite with it largely, and form liquid compounds of decidedly acid taste and quality. H. 1. 297.

Nitrous Oxide.

409. *Protoxide of Nitrogen*, or *nitrous oxide*, may be obtained by several processes. By dissolving zinc, or tin, in nitric acid, diluted with five or six times its weight of water. Zinc, during this solution disengages nitrous oxide till the acid begins to exhibit a brownish colour, when the process must be suspended, as nitrous gas is then formed. But the gas thus obtained is impure.

Process for obtaining.

410. To procure it in a state of purity, a salt, to be hereafter described, called *nitrate of ammonia*, is heated in a retort over an Argand lamp. The heat should not be raised beyond 440° F. The salt will presently liquefy, and must be kept gently simmering, avoiding violent ebullition. The gas may be col-

lected over water, and allowed to stand a few hours before it is used, during which time it will deposit a white substance, and become perfectly transparent.

A gazometer best adapted for its reception.

411. A gazometer, however, is best adapted for its reception, because all danger is then avoided of the water of the trough being forced into the retort; and because the gas is brought into contact with a much smaller surface of water, which has the property of absorbing a considerable proportion of the gas. On this account, water which has been once used to confine the gas, may be kept for the same purpose.

Theory of this process.

412. The changes that take place during the conversion of nitrate of ammonia into nitrous oxide, are the following. Nitric acid is composed of oxygen and nitrous gas, ammonia of hydrogen and nitrogen. In a high temperature, the nitrous gas combines with an additional dose of nitrogen, and forms nitrous oxide; while the oxygen of the decomposed nitric acid unites with the hydrogen of the ammonia, and forms water.

Synonyms, &c.

413. The gas thus obtained, was termed, by its discoverer, Dr Priestley, *dephlogisticated nitrous air;* by the Dutch chemists *gaseous oxide* of *azote.* Its most appropriate title is *protoxide of nitrogen.*[*]

Method of ascertaining its purity.

414. In order to ascertain whether nitrous oxide be adulterated with either common air or oxygen gas, we may mix equal measures of the gas under examination, and of nitrous gas. If any diminution ensue, the presence of one of these may be suspected; and the amount of the diminution will show which of them is contained in it. Nitrous gas, however, is a much more common contamination; for it is generated, along with nitrous oxide whenever the temperature of the salt is raised too high. Its presence may be detected, either by red fumes and a diminution on the admixture of oxygen gas; or by an absorption being effected, on agitating the gas with a solution of green sulphate of iron, which has no action on pure nitrous oxide. H. 1. 302.

Specific gravity.

415. It is considerably heavier than common air. Sir H. Davy has stated 100 cubic inches (at 30 inches pressure and at 60° F.) to weigh between 48 and 49 grains; and hence its specific gravity should be very nearly 1,6. According to Dr Thomson, 100 cubic inches weigh 46,5972 grs, and its specific gravity, air = 1, is 1,5277; oxygen = 1, 1,375.

Properties.

The taste of this gas is sweet, and its smell peculiar, but agreeable.

It is easily absorbed by water, which takes up about its own bulk, and evolves it unchanged when heated.

Its singular effects, resembling intoxication, when respired, were first ascertained by Sir H. Davy. (*Researches Chemical and Philosophical, chiefly concerning Nitrous Oxide.* London, 1800.) The experiment of breathing this gas, however, cannot be made with impunity, especially by those who are liable to a determination of blood to the head.

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[*] For a full account of this gas, see Sir H. Davy's Researches, Lond. 1800.

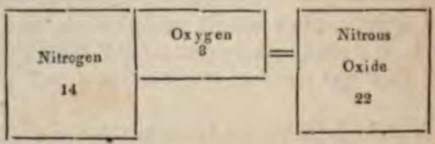
Exp'ts. 416. Nitrous oxide supports combustion, and a taper introduced into it has its flame much augmented and surrounded by a purplish halo. Phosphorus and sulphur, when introduced in a state of vivid ignition into this gas, are capable of decomposing it, and burn with the same appearance nearly as in oxygen; but, if when put into the gas, they are merely burning dimly, they then do not decompose it and are extinguished, so that they may be melted in the gas, or even touched with a red hot wire without inflaming, (but when wire intensely heated, or made white hot, is applied, the phosphorus burns, or rather detonates, with prodigious violence. H.) Charcoal, and many of the metals, also decompose nitrous oxide at high temperatures.

Decomposition. 417. At a red heat this gas is decomposed and converted into nitrogen and nitric oxide, undergoing at the same time an increase of bulk. For experiments of this kind the following simple apparatus may be used: It consists of two bladders, fig. 99, one of which is filled with the gas, and the other empty, attached to the extremities of a porcelain tube which traverses the body of a furnace. The bladders are supplied with stopcocks, and the gas is squeezed from one to the other when the tube is red hot.

Analysis of nitrous oxide. 418. The best analysis of this gas is effected by detonation with hydrogen; one volume of nitrous oxide requires one volume of hydrogen. This mixture fired by the electric spark, produces water, and one volume of nitrogen remains. Now, as one volume of hydrogen takes half a volume of oxygen to form water, nitrous oxide must consist of two volumes of nitrogen and one volume of oxygen; these three volumes being so condensed in consequence of chemical union, as only to fill the space of two volumes. The specific gravity of nitrogen compared with oxygen, is as 14 to 16; nitrous oxide, therefore, consists of

14 Nitrogen
8 Oxygen
—
Number for nitrous oxide, = 22*

or,



Nitrous gas. 419. *Nitric oxide, deutoxide of nitrogen, or nitrous gas.*—This gas, though discovered by Dr Hales, was first examined by Dr Priestley, and called by him *nitrous* air, a term afterwards changed to *nitrous gas*, then to *nitric oxide*, and more lately to *deutoxide of azote*, or *deutoxide of nitrogen*, which last appears to be its most appropriate title. It is more generally known, however, under the name of nitrous gas. H.

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* Taking oxygen as = 1 the atomic weight of nitrous oxide is 2,75. T.

How obtained.

420. It is usually obtained by presenting certain substances to nitric acid, which abstract a portion of its oxygen, leaving the remaining elements in such proportions as to constitute the gas in question; for this purpose some copper filings may be put into a gas bottle, fig. 65, with nitric acid, diluted with thrice its bulk of water; an action ensues, red fumes are produced, and there is a copious evolution of the gas, which may be collected and preserved over water. The first portions should be rejected as containing nitrogen and nitrous acid gas. Nitric oxide is presently recognized by the red fumes which it produces when brought into the contact of air. During this process part of the nitric acid gives oxygen to the copper; and passes to the state of nitrous gas, and the remaining acid unites with the deutoxide of copper, and composes the deutonitrate of that metal.

Theory of the process.

421. Quicksilver may be substituted for the copper; but in the latter case it will be found necessary to apply heat to the materials. H. 1. 306.

Effect of oxygen.

422. When mixed with oxygen gas red fumes arise, heat is evolved, a diminution takes place, and if the two gases be in proper proportion, and perfectly pure, they disappear entirely. The product of this union is possessed of acid properties, which may be shown by the following experiment.

Exp.

Paste a slip of litmus-paper within a glass jar, near the bottom; and into the jar, filled with and inverted in water, admit as much nitrous gas, previously well washed, as will displace the water below the level of the paper. The colour of the litmus will remain unchanged; but on adding oxygen gas it will be immediately reddened. H. 311.

Specific gravity.

423. Nitrous gas is rather heavier than common air; 100 cubic inches at 60° F. barometer 30, weigh 32 grains, and its specific gravity is 1,050 (*Davy.*) According to Dr Thomson 100 cubic inches weigh 31,7708 grains and its specific gravity is 1,04166, air = 1, or 0,9375 oxygen = 1. Its specific gravity to hydrogen is as 15 to 1.

Properties.

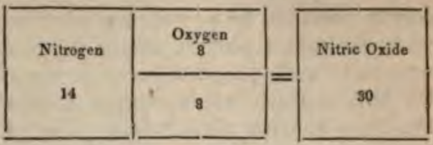
424. When it has been washed with water it is not acid, as proved by the colour of litmus remaining unchanged by it. (422.)

425. It extinguishes most burning bodies; but phosphorus readily burns in it if introduced in intense ignition. Mingled with hydrogen gas it imparts a green colour to its flame.

Decomposition.

426. It is not altered by a red heat, nor does it detonate when mixed with hydrogen and subjected to the electric spark; but it may be decomposed by the action of some of the metals at high temperatures, which absorb its oxygen. One volume of nitric oxide is thus resolved into equal volumes of oxygen and nitrogen. If therefore we call nitrous oxide a compound of 1 proportional, or atom, of nitrogen + 1 of oxygen, then nitric oxide may be considered as consisting of 1 nitrogen + 2 oxygen,

or by weight, 14 nitrogen + 16 oxygen, and its symbol will stand thus :



427. Nitrous gas is decomposed by exposure to almost all bodies that attract oxygen. Thus iron filings decompose it, and become oxidized, affording a proof of the presence of oxygen in this gas. During this process, water, ammonia, and nitrous oxide, in the proportion of one volume from two of nitrous gas, are generated. Sulphuret of potash, &c. have a similar effect. Sulphuret of barytes gives one half its volume of nitrogen. Mixed with sulphurous acid, nitrous gas is decomposed, and this acid is changed into the sulphuric, but not unless water is present.* Nitrous gas, does not, with hydrogen gas, afford a mixture that can be exploded by the electric spark; but, with ammoniacal gas, it may be fired in a Volta's eudiometer over mercury. The oxygen of the nitrous gas unites with the hydrogen of the ammonia, and the nitrogen of both gases is set at liberty. H 1. 311.

Exp. A piece of glowing charcoal plunged into nitric oxide gas is presently extinguished, but if it be passed through a porcelain tube containing red hot charcoal, nitrogen and carbonic acid and oxide are produced. B.

Hypo-nitrous acid. 428. *Nitric Oxide and Chlorine*, when both are perfectly dry, exert no mutual action, but the presence of water causes an immediate change; it is decomposed, and, furnishing oxygen to the nitric oxide, and hydrogen to the chlorine, nitrous acid and muriatic acid gases are generated. It was the presence of water which misled those, who thought that the red fumes produced by mixing nitric oxide and chlorine not carefully dried, resulted from the existence of oxygen in chlorine.

429. Gay-Lussac has concluded from his experiments that there exists a compound of nitrogen and oxygen intermediate between nitric oxide and nitrous acid, which he has termed *per-nitrous acid*, but to which the term *hypo-nitrous acid* is more applicable. He considers it as a compound of 1 proportional of nitrogen, and 3 of oxygen.

Its existence hypothetical. When 400 measures of nitrous gas, and 100 measures of oxygen (in which, taken together, the nitrogen and oxygen are to each other by measure as 100 to 150) are mixed together over a solution of potash confined by mercury, we obtain 100 measures of this compound,† which however, is so far hypothetical that it has never yet been exhibited in a separate form, for when a stronger acid is added, to expel it from the potash, it is resolved into nitrous gas and nitrous acid.

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* Nicholson's Jour. xvii. 43.

† Ann. de Chimie et Phys. I. 400.

Composition.

Calculating from the proportions of its elements, and their state of condensation, 100 cubic inches of hypo-nitrous acid must weigh 80,2 grains, and it must consist in 100 grains of

	Vols.	Atoms.	By weight.	
Nitrogen	1	1	36,8	100
Oxygen	1,5	3	63,2	171,74
	2,5		100,	H. 1. 314.

Nitrous acid gas.

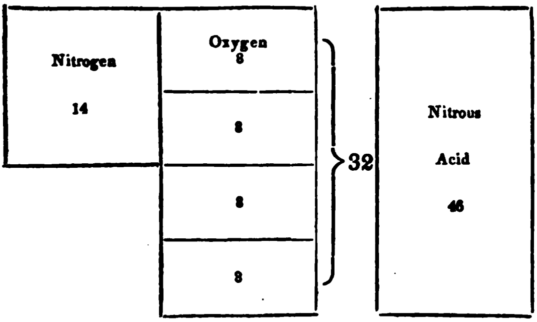
430. *Nitrous Acid Gas.*—When nitric oxide is presented to oxygen, the two gases combine, and a new gaseous compound of a deep orange colour results. This compound is not easily examined, because it is absorbed both by quicksilver and water, so that we are obliged to resort to exhausted glass vessels for its production. When we thus mix two volumes of nitric oxide with one volume of oxygen, the gases become condensed to about half their original volume, and form *nitrous acid gas.*

Properties.

431. This gas supports the combustion of the taper, of phosphorus, and of charcoal, but extinguishes sulphur. It is readily absorbed by water, forming a green sour liquid. Its specific gravity to hydrogen is as 23 to 1, and 100 cubic inches weigh 48,69 grains.

Composition.

It is obvious that this nitrous acid gas must consist of 14 nitrogen + 32 oxygen, and therefore, its number is 46; for nitric oxide is composed of equal volumes of nitrogen and oxygen, and one additional volume of oxygen, or two proportionals by weight, are added to form nitrous acid.



Absorbed by water.

432. If the mixture of nitric oxide and oxygen be made over water, in the above proportions, and if the gases be perfectly pure, complete absorption takes place; but if either the oxygen or nitric oxide contain uncombined nitrogen it will remain unabsorbed.

Liquid nitrous acid.

433. To form liquid nitrous acid, nothing more is necessary than to saturate water with this vapour. The water becomes first green, then blue, and finally an orange colour, more or less deep. The latter may be brought to the state of green or blue by adding more or less water. Hence the colour depends merely on the circumstance of density. H. 1. 315.

Properties differ from those of nitric acid.

434. The properties of liquid nitrous acid, Berzelius remarks,[*] differ from those of nitric acid; for while the latter boils at 236°, nitrous acid of the same density boils at 160°. The purely acid part, he considers to be composed of 36,9 nitrogen + 63,1 oxygen. With bases, it forms a class of salts, which, he asserts, differ entirely from those containing nitric acid. On the other hand, we have the testimony of Gay-Lussac, that the nitrous acid is decomposed with so much facility by contact with alkaline solutions, as to be incapable of forming a distinct class of salts. With solution of potash, for example, he found that it affords pernitrite and nitrate, but nothing that can properly be called a nitrite of potash.[†]

Nitric acid.

435. *Nitric Acid.*—The fifth compound of nitrogen with oxygen is the nitric acid; the nature of which was first demonstrated by Mr Cavendish, in 1785. (***Phil. Trans.***) It is usually obtained by the distillation of purified nitre with sulphuric acid, of which materials different proportions are employed.

Process for obtaining.

Into a glass retort, which may be either tubulated or not, put four parts by weight of nitrate of potash, reduced to a coarse powder, and pour upon it three parts of concentrated sulphuric acid. Apply a tubulated receiver of large capacity, between which, and the retort, an adopter may be interposed; these junctures being luted with a mixture of pipe-clay, sifted sand, and cut tow or flax. To the tubulure of the receiver, a glass tube may be fixed by means of the fat lute,[‡] and may terminate in another large receiver, containing a small quantity of water.

If the operator wishes to collect the gaseous products also, this second receiver should be provided with a tubulure, to which a bent pipe may be luted, terminating under one of the inverted funnels in the shelf of the pneumatic trough. Apply heat to the retort, through the intervention of a sand-bath. The first product, that passes into the receiver, is generally of a red colour, and of a smoking quality. These appearances gradually diminish; and if the materials used were clean, the acid will come over pale, and even colourless. Afterwards it gradually re-assumes a red colour, and smoking property; which appearances go on increasing till the end of the operation; and the whole product, mingled together, has either a yellow or an orange colour, according to the temperature employed. H. 1. 318.

436. The nitric acid of commerce, which is generally red and fuming in consequence of the presence of nitric oxide, is procured by the distillation of two parts of nitre with one of sulphuric acid; these proportions afford about one part of orange-coloured nitric acid of the specific gravity of 1,48. Upon the large

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[*] 13 Ann. de Chim. 10.

[†] Ann. de Chim. et Phys. i. 409.

[‡] Formed by beating perfectly dry and finely sifted tobacco pipe clay, with painters' drying oil.

scale 112 lbs of nitre, and 56 of sulphuric acid yield from 50 to 52 lbs of nitric acid. Some manufacturers employ three parts of nitre and two of sulphuric acid, and the *London Pharmacopœia* directs equal weights, by which a nearly colourless nitric acid is afforded.

Proportions of acid and water.

It will appear by referring to the article *Sulphuric Acid*, that it contains in its liquid state one proportional of dry acid, and *one* of water; whereas liquid nitric acid contains one proportional of dry acid, and *two* of water; hence the requisite excess of sulphuric acid, where colourless and perfect nitric acid is to be obtained; hence too the red colour of the acid of commerce in consequence of the smaller quantity of sulphuric acid generally used by the manufacturer. This will be more apparent by reference to the article *Bi-sulphate of Potassa*.[*]

The distillation of nitric acid may be conducted upon the small scale in a tubulated glass retort *a*, with a tubulated receiver *b*, passing into the bottle *c*, fig. 100. The requisite heat is obtained by the lamp *d*, and the whole apparatus supported by the brass stands with sliding rings *e e*.

Preparation of nitrous acid, or aquafortis.

But the manufacturer who prepares nitric acid upon a large scale, generally employs distillatory vessels of stone-ware. Fig. 101 represents the arrangement of the distillatory apparatus, employed at Apothecaries' Hall, London, for the production of common *aquafortis:* it consists of an iron pot, set in brick-work, over a fire-place; an earthenware head is luted upon it, communicating with two receivers of the same material, furnished with earthenware stop-cocks, the last of which has a tube of safety dipping into a basin of water.

Purification of nitric acid.

437. The nitric acid of commerce, as obtained by the above processes, is always impure, and muriatic and sulphuric acids may usually be detected in it. The former may be separated by *nitrate of silver*, and the latter by a very dilute solution of *nitrate of baryta*. To obtain *pure nitric acid*, therefore, add to that of commerce a solution of nitrate of silver, as long as it produces any white precipitate; and when this has subsided, pour off the clear liquor, and add, in the same way, the nitrate of baryta; then distil the acid, and it will pass over perfectly pure. For pharmaceutical purposes, the ordinary acid is generally sufficiently pure. If, however, pure nitre, and pure sulphuric acid be employed in its production, and the latter not in excess, there is little apprehension of impurity in the resulting acid.

Composition.

438. Nitric acid in its dry state, that is, as it exists combined with metallic oxides in the salts called *nitrates*, may be regarded as composed of one proportional of nitrogen = 14, and 5 of

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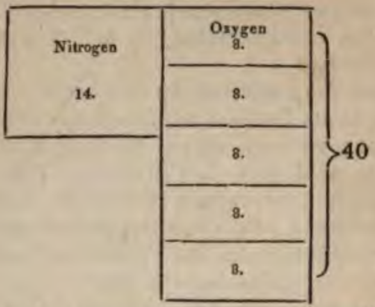
[*] If it be required to decompose the whole of any portion of nitre, it is necessary to use as much sulphuric acid, as will form, with the alkali of the nitre, *bi-sulphate* of potash, *viz.* 97 parts of acid, of density 1,85 to 100 parts of nitre. H. 1. 319.

oxygen = 40, and this will be the symbol representing its composition,



Consequently, the representative number of *dry* nitric acid is 54,0. But in its liquid state it always contains water; and when in this state its specific gravity is 1,5, it may be regarded as a compound of one proportional of dry acid and two of water, which may be numerically expressed thus:

$$\overset{\text{Acid.}}{54.} + \overset{\text{Water.}}{18} = 72, \text{ liquid acid.}$$

Properties of liquid nitric acid.

439. Liquid nitric acid is heavier than water, in the proportion of 1,5 or upwards to 1. Proust obtained it as high as 1,62; and the specific gravity of real nitric acid, which cannot, however, be obtained separately, may be calculated at 1,75. In its heaviest form, it still contains a portion of water, which is essential to its existence in a liquid state, and without which its elements would separate from each other. In acid of the sp. gr. 1,50 the water amounts, calculating from the data furnished by Dr Wollaston, to 25,11 grains in 100 grains of acid; or, according to Mr R. Phillips, to 25,09. According to Sir H. Davy, the strongest acid (sp. gr. 1,55) contains 14,4 parts of water in 100; and acid of sp. gr. 1,42 contains 25,2 of water in 100. (*Elements*, p. 265.)

440. Nitric acid is usually coloured by nitrous acid gas, to expel which, put the acid into a retort to which a receiver is applied, the two vessels not being luted, but joined merely by paper. Apply a very gentle heat for several hours to the retort, changing the receiver as soon as it becomes filled with red vapours. The nitrous gas will thus be expelled, and the nitric acid will remain in the retort limpid and colourless. It must be kept in a bottle secluded from light. H. 320.

441. Hidro-nitric acid emits white fumes when exposed to the air, and is extremely sour and corrosive.

It gives a yellow stain to the skin.

It boils at 248° Fahrenheit, and may be distilled over without any essential change. This, however, is true only of acid of the specific gravity 1,42; for an acid, weaker than this, is strengthened by being boiled; while an acid, stronger than 1,42, becomes weaker by boiling. All the varieties of nitric acid, therefore, are brought by sufficient boiling to the specific gravity 1,42.

May be frozen.

442. Hydro-nitric acid may be frozen by the application of a sufficiently low temperature. Like sulphuric acid, there is a certain point of density at which it most readily congeals. Mr Cavendish has described this, not by its specific gravity, but by the quantity of marble which it is capable of dissolving. When it takes up $\frac{418}{1000}$ths of its weight, in which case its specific gravity is 1,3, the acid freezes at 2° below 0 Fahrenheit. When considerably stronger and capable of dissolving $\frac{561}{1000}$ths, it required cooling to—41,6; and when so much diluted as to take up only $\frac{276}{1000}$ths, it did not congeal till cooled to—40,3.*

Absorbs moisture.

443. Strong hydro-nitric acid absorbs moisture from the atmosphere; in consequence of which it increases in weight, and diminishes in specific gravity.

444. When two parts of the acid are suddenly diluted with one of water, an elevation of temperature is produced to about 112° F.; and the admixture of 58 parts by weight of acid of specific gravity 1,50 with 42 parts of water, both at 60° F., gives a temperature of 140°†. When more water is added to this diluted acid, its temperature is reduced. Snow or ice added to the cold dilute acid is instantly liquefied, and an intense degree of cold is produced.

Effect of solar light.

445. It becomes coloured by exposure to the sun's light, passing first to a straw colour, and then to a deep orange. This effect is produced by the union of the light of the sun with oxygen, in consequence of which the proportion of the acidifying principle to the nitrogen is diminished.

446. By exposing it to the sun's rays in a gas bottle, the bent tube of which terminates under water, oxygen gas may be procured. H. 1. 321.

Uses.

447. Nitric acid is of considerable use in the arts. It is employed for etching on copper, as a solvent of tin to form with that metal a mordant for some of the finest dyes; in metallurgy and assaying; in various chemical processes, on account of the facility with which it parts with oxygen and dissolves metals; in medicine as a tonic, &c. For the purposes of the arts it is commonly used in a diluted state, and contaminated with the sulphuric and muriatic acids, by the name of *aqua-fortis*. This is generally prepared by mixing common nitre with an equal weight of sulphate of iron, and half its weight of the same sulphate calcined, and distilling the mixture; or by mixing nitre with twice its weight of dry powdered clay, and distilling in a reverberatory furnace. Two kinds are found in the shops, one called *double aquafortis* which is about half the strength of nitric acid; the other simply *aquafortis*, which is half the strength of the double. U. 72.

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* Phil. Trans. 1788.

† Dr Ure.

Decomposed by combustibles.

448. This acid retains its oxygen with but little force,—hence it is decomposed by all combustible bodies, which are oxygenized by it, with more or less rapidity in proportion to their affinity for oxygen.

Exp.

Poured on perfectly dry and powdered charcoal it excites the combustion of the charcoal, which becomes red hot, and emits an immense quantity of fumes.

It also inflames essential oils when suddenly poured on them.

Exp.

Into a gallipot, placed upon a hearth and containing about a table-spoonful of oil of turpentine, pour about half the quantity of strong nitrous acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine a large quantity of dense smoke will be produced, often accompanied with flame. The acid should be poured from a bottle tied to the end of a long stick, otherwise the operator's eyes may be severely injured.

And metals.

449. It is also decomposed by metals, as iron, tin, zinc, copper, &c. and with different phenomena, according to the affinity of each metal for oxygen.

Exp.

This may be seen by pouring some strong nitric acid on iron filings, or powdered tin. The acid must be of greater density than 1,48, otherwise it will not produce the effect. Violent heat, attended with red fumes, will be produced, and the metals will be oxidized. H. 1. 323.

And by a red heat.

450. Nitric acid may be decomposed by passing its vapour through a red hot porcelain tube; oxygen is given off, nitrous acid gas is produced, and a quantity of diluted acid passes over into the receiver, having escaped decomposition; so that it is thus proved to consist of nitrous acid gas, oxygen and water.

For experiments of this kind the form of apparatus, described for the decomposition of water by iron (351), may be employed, omitting the condensing worm-pipe.

Synthesis.

The nature of nitric acid was first synthetically demonstrated by Mr Cavendish, who passed electric sparks through a portion of atmospheric air, or through a mixture of one part of nitrogen and two of oxygen, confined over mercury. After some time the mixture diminished in bulk, and, on admitting a little water, an acid solution was obtained, which afforded crystals of nitre when saturated with potassa.

Aqua-Regia.

451. *Nitro-muriatic Acid.*—This term has been applied to the *Aqua Regia* of the alchemists. When nitric and muriatic acids are mixed, they become yellow, and acquire the power of readily dissolving gold, which neither of the acids possessed separately. This mixture evolves chlorine, a partial decomposition of both acids having taken place, and water, chlorine, and nitrous acid gas. are thus produced; that is, the hydrogen of the muriatic acid abstracts oxygen from the nitric to form water: the result must be chlorine and nitrous

acid.—DAVY, *Journal of Science and the Arts*, Vol. i. p. 67.

For every 101 parts in weight of real nitric acid (equivalent to 118 of hydro-nitric acid) which are decomposed, 67 parts of chlorine, Sir H. Davy calculates, are produced. According to this view it is not correct to say that *aqua regia* oxidates gold or platinum, since it merely causes their combination with chlorine. By long continued and gentle heat, nitro-muriatic acid may be entirely deprived of chlorine, and it then loses its power of acting on gold and platinum. H. 1. 325.

Chloride of Nitrogen.

452. *Nitrogen and Chlorine.—Chloride of Nitrogen.*— These gases do not unite *directly*, but the compound may be obtained by exposing a solution of *nitrate* or *muriate of ammonia* to the action of chlorine, at a temperature of 60° or 70°. The gas is absorbed, and an oil-like fluid, heavier than water, is produced. It is the most powerfully detonating compound with which we are acquainted. It was discovered by M. Dulong, in 1812.—*Annales de Chimie*, Vol. lxxxv.

Process for obtaining.

The simplest mode of obtaining this compound, consists in filling a perfectly clean glass basin with a solution of about one part of sal-ammoniac in twelve of water, and inverting into it a tall jar of chlorine. The saline solution is gradually absorbed and rises into the jar, a film forms upon its surface, and it acquires a deep-yellow colour; at length small globules, looking like yellow oil, collect upon its surface, and successively fall into the basin beneath, whence they are most conveniently removed by drawing them into a small and perfectly clean glass syringe, made of a glass tube drawn to a pointed orifice, and having a copper wire with a piece of clean tow wrapped round it for a piston; fig. 101, in this way a globule may be drawn into the tube, and transferred to any other vessel.

Properties.

453. Its specific gravity is 1,6653 water being 1, it is not congealed by cold. Its odour is irritating and peculiar; it very soon evaporates when exposed to air. This substance is decomposed with violent detonation by many combustibles, especially phosphorus, and fixed oils. Its discoverer M. Dulong was severely wounded in his first experiments on it; and Sir H. Davy had a serious injury done to his eyes in repeating them.

Precautions in experimenting with.

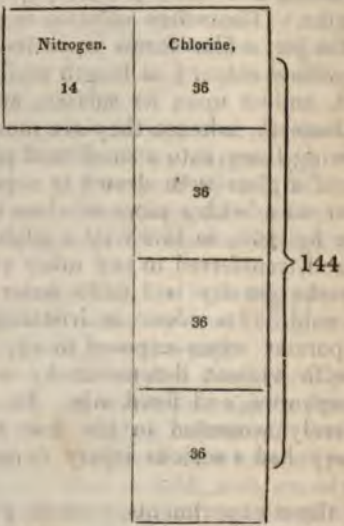
In making these experiments, a small globule of the compound, about the size of a mustard-seed, should be cautiously transferred to a clean porcelain basin, half filled with water. The basin should be covered with a wire safe-guard. A very small piece of phosphorus, fixed to the end of a long rod with the extremity dipped in oil may be then brought into contact with the globule, which instantly explodes, dispersing the water, and breaking the basin. At 160° it distils without change, but at 212° explodes, and is decomposed. It was submitted to the action of 125 different substances, by Messrs Porret and Wilson, of which the following caused it to explode.

Phosphorus.
Phosphuret of lime.
Caoutchouc.
Myrrh.
Palm-oil.
Whale-oil.
Linseed-oil.
Olive-oil.
Oil of turpentine.
Naptha.
Liquid ammonia.
Phosphuretted hydrogen.
Nitric oxide.

The metals, resins, and sugar did not cause it to explode.—Nicholson's *Journal*, Vol. xxxiv.

Composition of chloride of nitrogen.

454. Alcohol quickly changes it into a white substance. Mercury absorbs the chlorine and evolves nitrogen. It yields, by decomposition, 1 volume of nitrogen and 4 of chlorine ; and as the specific gravity of nitrogen to chlorine is as 14 to 36,0, so it may be said to consist of 1 proportional of nitrogen + 4 proportionals of chlorine, or $\overset{N}{14} + \overset{C}{144}$, by weight, and its number will be 158.



455. In the state of vapour, it is probable that the five volumes of aëriform matter which it affords by decomposition, are condensed into one, since its decomposition by mercury is not attended by any change of its volume.

Iodide of Nitrogen.

456. *Nitrogen and Iodine.—Iodide of Nitrogen.*—A compound of these bodies may be procured by pouring a solution of ammonia upon a very small quantity of iodine. Hydriodic acid is one product, and the other a brown powder, which detonates upon the slightest touch, and is resolved into nitrogen and iodine. It may be collected by pouring off the liquid, and

placing it, while moist, in small parcels upon bibulous paper, where it must be suffered to dry spontaneously.

Exp.

If we collect the powder on two or more separate pieces of paper, and place them at several inches apart, the explosion of any one of them will cause that of the others.

When it detonates, the purple fumes of iodine are perceptible, and it is converted into nitrogen gas and iodine; but all attempts to collect the products have failed, and we are ignorant therefore of the proportion of its components.

When left exposed it gradually evaporates.

Ammonia or volatile alkali.

457. *Nitrogen and Hydrogen—Ammonia;* or *Volatile alkali.*—Ammonia in its purest form exists in the state of a gas.

Process for obtaining.

It may be obtained by heating a mixture of *quicklime* and *muriate of ammonia* (*Sal ammoniac.*) Two parts of dry quicklime and one of muriate of ammonia, each separately powdered, may be introduced into a small glass retort, or gas bottle, and upon the application of a gentle heat the gas passes over. It must be received over mercury.

458. Persons not having a mercurial apparatus may receive this gas in a glass jar inverted over a tube bent as in fig. 102. As the gas is evolved from the materials contained in the gas-bottle, it rises into the jar and displaces the atmospheric air. When the jar is filled with ammonia (which will be known by its pungent odour as it escapes from the neck of the jar) the *tube* may be carefully withdrawn, and a well ground stopper be inserted into the neck of the jar.

Properties.

459. Ammonia is permanently elastic at common temperatures, extremely pungent and acrid, but when diluted by mixture with common air, agreeably stimulant. It converts most vegetable blues to green, and the yellows to red, properties which belong to the bodies called *alkalis.* Ammonia, therefore, has been termed *volatile alkali.*

Does not support combustion.

460. It extinguishes flame, and is fatal to animals. Before, however a candle is extinguished by immersion in this gas, the flame is enlarged, by the addition of another of a pale yellow colour, which descends from the mouth to the bottom of the jar. If the flame of the candle be only in part immersed in the gas, this yellowish flame rises a few lines above the other.

Exp.

May be inflamed in oxygen gas.

461. Ammoniacal gas is not sufficiently inflammable to burn when in contact with common air. But, when expelled from the extremity of a pipe, having a small aperture, surrounded by oxygen gas, it may be kindled, and it then burns with a pale yellow flame, the products of its combustion being water and nitrogen gas.

Absorbed by water.

462. Ammonia is rapidly absorbed by water. A drop or two of water being admitted to a jar of this gas, confined over mercury, the gas will be immediately absorbed, and the mercury will rise, so as to fill the whole of the jar, provided the gas be

Exp.

sufficiently pure. Ice produces the same effect in a still more remarkable manner, and liquid ammonia is produced.

Specific gravity.

463. Its specific gravity to hydrogen is as 8,5 to 1; 100 cubical inches weighing 18 grains, B. Air being = 1 its specific gravity is 0,59027. Oxygen = 1 it is 0,53125, and 100 cubic inches weigh 18,0035. T.

Exp.

464. When ammonia is presented to muriatic acid it unites with it and white vapours, composed of muriate of ammonia are formed. This will be evident if we moisten the inside of a glass jar with muriatic acid, and pass into it a small quantity of ammonia, dense clouds of muriate of ammonia will immediately form (37).

Phenomena attending the mixture of ammonia and chlorine.

Exp.

465. Chlorine and ammonia exercise so powerful an action on each other that when mixed suddenly, a sheet of white flame pervades them. The simplest way of making this experiment, is to invert a matrass with a conical neck and wide mouth, over another with a taper neck containing a mixture of sal ammoniac and lime, heated by a lamp. As soon as the upper vessel seems to be full of ammonia, by the overflow of the pungent gas, it is to be cautiously lifted up, and inserted, in a perpendicular direction, into a wide mouthed glass decanter or flask, filled with chlorine. On seizing the two vessels thus joined with the two hands, covered with gloves, and suddenly inverting them, like a sand-glass, the heavy chlorine and light ammonia, rushing in opposite directions, unite, with the evolution of flame. U. 158.

Liquor ammoniæ.

466. The usual state in which ammonia is employed is in solution, both in chemistry and medicine. This solution bears the name of Liquor Ammoniæ of the London Pharmacopœia.* It may be obtained by passing the gas into water in a proper apparatus, fig. 81, or by distilling over the water and gas together.

Mr Phillips's process.

The following process, recommended by Mr Phillips answers well. On 9 ounces of well-burned lime pour half a pint of water, and when it has remained in a well closed vessel for about an hour, add 12 ounces of muriate of ammonia in powder and three pints and a half of boiling water; when the mixture has cooled, pour off the clear portion, and distil from a retort 20 fluid ounces. The specific gravity of this solution, which is sufficiently strong for most purposes, is 0,954—*Remarks on London Pharmacopœia*, p. 34.

The specific gravity of the officinal solution directed in the *Pharmacopœia*, is 0,960.

467. Liquid ammonia should be preserved in well-stopped glass bottles, since it loses ammonia and absorbs carbonic acid, when exposed to air. When heated to about 140°, ammonia is rapidly given off by it; when concentrated it requires to be cooled to — 40° before it congeals, and then it is apparently inodorous.

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* Aqua Ammoniæ of the United States Pharmacopœia.

nitrogen gases, furnishing a singular instance of change of properties in consequence of chemical combination. *a* fig. 103, is a bladder filled with ammonia which may be passed through the iron tube *b*, placed in the furnace *c*; the gas is decomposed, and hydrogen and nitrogen may be collected over the water in *d*.

Ammonia is also decomposed when passed over black oxide of manganese, heated red-hot in a porcelain tube; the results are water and nitrous acid gas; nitrate of ammonia is also often formed.

Synthesis. 472. Ammonia is produced synthetically during the decomposition of many animal substances; it is also formed during the violent action of nitric acid upon some of the metals; and by moistened iron-filings exposed to an atmosphere of nitrogen; in these cases the nascent gases unite so as to form a portion of ammonia.

Salts of ammonia. 473. Ammonia combines with the acids, and produces a class of salts which, with very few exceptions, are soluble in water, and which evolve the odour of ammonia when mixed with lime or with pure potassa. These salts are, for the most part, entirely dissipated, and, generally speaking, decomposed by heat.

Chlorate of ammonia. 474. *Ammonia and chloric acid—Chlorate of Ammonia* is formed by saturating chloric acid with carbonate of ammonia. It forms very soluble acicular crystals, of a sharp taste, which detonate when thrown upon hot coals. It probably consists of 1 proportional of each of its components, and 17 ammonia + 76 chloric acid.

Iodate. 475. *Iodate of Ammonia* forms small indeterminate crystals; when heated they are decomposed into oxygen, nitrogen, water and iodine.—When heated in close tubes, the tubes are frequently burst; but Gay-Lussac succeeded in collecting the products, which were equal volumes of oxygen and azotic gases. He states its composition at 100 acid + 10,94 ammonia, or 2 vols. of gaseous ammonia, 1 volume of iodine in vapour, and 2½ volumes of oxygen. H. 405.

476. *Ammonia and Chlorine.* No compound of chlorine and ammonia can exist, for as soon as ammonia is brought into contact with chlorine, it is decomposed in the manner already described (456) H. On mixing 15 parts of chlorine and 40 of ammonia, 5 parts of nitrogen are liberated and muriate of ammonia is formed. B.

Sal-ammoniac. 477. *Ammonia and Muriatic Acid—Muriate of Ammonia—Hydrochlorate of Ammonia—Sal-Ammoniac.*—This salt may be produced directly by mixing equal volumes of ammonia and muriatic acid, when an entire condensation ensues (37).

This may be shown by means of the apparatus fig. 53. Into one of the retorts a small quantity of muriatic acid (or the materials from which the acid gas is usually obtained (371) is introduced; and into the other liquid ammonia (or the mixture of lime and muriate of ammonia (457). The evolved gases passing into the cylinder unite producing dense clouds of muriate of ammonia which concrete upon the inner surface of the cylinder.

Exp.

478. We may also form muriate of ammonia by mixing over mercury, equal measures of ammoniacal gas, and muriatic acid gas, which are entirely condensed into a white solid.

Composition.

479. It is easy to calculate the composition of this salt, for since 100 cubic inches of muriatic acid gas weigh 39 grains[*] and the same volume of ammonia weighs 18,18 grains,[†] muriate of ammonia must consist of

		Atoms.	
Muriatic acid	68,205 . . .	1 . . .	37
Ammonia	31,745 . . .	1 . . .	17
	100,		54

But in its ordinary state, th[illegible]tains water, the proportion of which, according to B[illegible] as follows

		Atoms.	
Muriatic acid	[illegible] . . .	1 . . .	37
Ammonia	[illegible] . . .	1 . . .	17
Water	[illegible] . . .	1 . . .	9
	100,		63.

H. 1. 406.

May be sublimed.

480. Muriate of ammonia when heated sublimes in the form of white vapour; and may even be passed through glass or porcelain tubes heated to redness, without alteration.

Other properties.

481. It is readily soluble in water, three parts and a half of which at 60°, take up one of the salt. During its solution much caloric is absorbed. It is still more soluble in boiling water, from which it crystallizes on cooling. On the addition of a solution of pure potash, soda, or lime, the alkali is disengaged, as is evinced by the pungent smell that arises. This may be proved by rubbing together in a mortar muriate of ammonia and quicklime.

Exp.

482. Though generally considered as a neutral salt, yet, if placed on litmus paper and moistened, Berzelius observes, that the paper is reddened after some moments, as it would be by an acid.

483. It is decomposed by baryta, strontia, lime and magnesia. H.

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[*] 39,1339 }
[†] 18,0035 } air = 1. Thomson's *First Prin.*

Whence obtained.

484. Muriate of ammonia was formerly imported from Egypt, where it was obtained by burning the dung of camels; it is now abundantly prepared in various parts of Europe. Its preparation will be hereafter described. When obtained by evaporation from its solution in water it forms octoëdral and plumose crystals; but in commerce it usually occurs as procured by sublimation, in white cakes, hard, and somewhat elastic, and in this compact state it requires for solution 3,25 parts of water at 60°.

Uses.

485. Sal-ammoniac is used in the arts for a variety of purposes, especially in certain metallurgic operations. It is used in tinning, to prevent the oxidation of the surface of copper; and small quantities are consumed by dyers. Dissolved in nitric acid, it forms the *aqua regia* of commerce, used for dissolving gold, instead of a mixture of nitric and muriatic acids (451.)

Native.

486. *Native Muriate of Ammonia* occurs massive and crystallized, in the vicinity of volcanoes, and in the cracks and pores of lava near their craters. It has thus been found at Etna, and at Vesuvius, in the Solfaterra near Naples, and in some of the Tuscan Lakes. An efflorescence of native sal-ammoniac is sometimes seen upon pit-coal. Its colour varies from the admixture of foreign matter, and it is frequently yellow from the presence of sulphur. It is said that considerable quantities of native sal-ammoniac are also found in the country of Bucharia, where it occurs with sulphur in rocks of indurated clay. The ancients, according to Pliny, called this salt *ammoniac*, because it was found near the temple of Jupiter Ammon, in Africa.

Origin of the name.

Hydriodate of ammonia.

487. *Hydriodate of Ammonia.*—In a former paragraph (456) the action of iodine on ammonia has been stated to produce a portion of hydriodate of ammonia: this compound may be directly formed by mixing equal volumes of hydriodic and ammoniacal gases; or by saturating liquid hydriodic acid by carbonate of ammonia; it forms very soluble and deliquescent cubic crystals, volatile in close vessels without decomposition. —Gay-Lussac, *Annales de Chim.* xci.

Nitrate of ammonia.

488. *Ammonia and Nitric Acid—Nitrate of Ammonia.*—This salt may be procured by the direct union of ammonia with nitric acid; or more easily, by saturating dilute nitric acid with carbonate of ammonia. It has been mentioned as the source of nitrous oxide, and when heated is entirely resolved into that gas and water. * It consists of one proportional of nitric acid = 54 + one proportional of ammonia = 17, and therefore the representative number of nitrate of ammonia is 71. Or it may be considered as containing two proportionals of nitrogen, three of hydrogen, and five of oxygen, as the following symbols show:

Composition.

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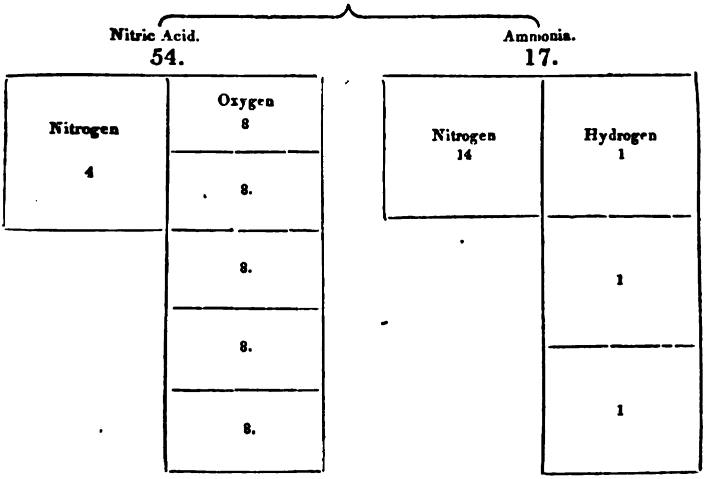
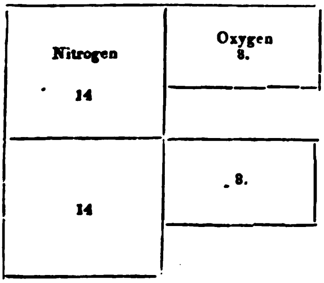
* Its specific gravity compared with water, is 1,5785. (Fourcroy.)

Nitrate of Ammonia.

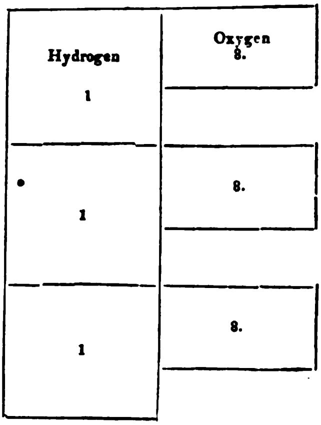


Nitrous oxide consists of 1 proportional of nitrogen = 14 + 1 of oxygen = 8; hence the 2 proportionals of nitrogen in the salt (1 in the acid and 1 in the ammonia) will require 2 of oxygen to produce nitrous oxide, and the remaining 3 of oxygen will unite to the 3 of hydrogen, and form water; and accordingly nitrous oxide and water are the only possible results; so that the elements after the decomposition of the salt, are arranged thus:

Two proportionals of Nitrous Oxide.



Three proportionals of Water.



489. Nitrate of ammonia has long been known, and was formerly called *Nitrum flammans*. It differs in form according to the manner in which its solution has been evaporated; if at a temperature below 100°, its crystals are six-sided prisms terminated by six-sided pyramids; if boiled down, its crystals are

Proportions of water.

thin and fibrous: it is deliquescent, and soluble in twice its weight of water at 60°, and in its own weight at 212°. Its taste is acrid and bitter. It contains different proportions of water of crystallization; according to Berzelius, the prismatic variety affords 11,232 *per cent.* (80 *Annales de Chimie.*) According to Davy, the fibrous variety contains 8,2 *per cent.;* and the compact, obtained by evaporating the solution till it concretes, 5,7 *per cent.* of water of crystallization.—DAVY's *Researches*, p. 71.

Atmospheric air.

490. *Atmospheric Air.*—The composition of atmospheric air has been frequently alluded to in the preceding pages, and as the student is now acquainted with its essential component parts, namely, oxygen and nitrogen, it may be right to consider its properties more at length.

Properties.

The atmosphere is a thin, transparent, invisible, and elastic fluid, which surrounds our planet and reaches to a considerable height above its surface, probably about 45 miles.

491. That air is a ponderous body, was first suspected by Galileo, who found that a copper ball, in which the air had been condensed, weighed heavier than when the air was in its ordinary state of tension. The fact was afterwards demonstrated by Torricelli, whose attention was drawn to the subject by the attempt of a well-digger at Florence, to raise water by a sucking-pump to a height exceeding 33 feet. It was then found that the pressure of the atmosphere, and not nature's abhorrence of a vacuum, was the cause of the ascent of the water in the pump-pipe, and that a column of about the height mentioned was sufficient to equipoise the atmosphere.

Barometer.

In 1643, Torricelli filled a glass tube, three feet long and closed at one end, with quicksilver, and inverted it in a basin of the same fluid; he found that the mercury fell about six inches, so that the atmosphere appeared capable of counterbalancing a column of mercury 30 inches in height. The empty space, in the upper part of the tube, has hence been called the *Torricellian vacuum*, and is the most perfect that can be formed.

Paschal and Torricelli afterwards observed, that upon ascending a mountain, the quicksilver fell in the tube, because there was less air above to press upon the surface of the metal in the basin; and thus a method of measuring the heights of mountains by the *barometer*, as the instrument is now called, was devised. Sir Henry Englefield has constructed a barometer, expressly for these investigations, the mode of using which is described in the *Journal of Science and the Arts*, Vol. v. p. 229.

The barometer indicates, by its rise and fall, a corresponding change in the density of the atmosphere. At the surface of the earth the mean density or pressure is considered equal to the support of a column of quicksilver 30 inches high.

	Inches.
At 1000 feet above the surface the column falls to	28,91
2000	27,86
3000	26,85
4000	25,87
5000	24,93
1 Mile	24,67
2	20,29
3	16,68
4	13,72
5	11,28
10	4,24
15	1,60
20	0,95*

Air pump.

492. The general mechanical properties of the air are best illustrated by the *air-pump*, the construction of which much resembles that of the common sucking-pump used for raising water, excepting that all the parts are more accurately and nicely made, the object being to exhaust the air as completely and expeditiously as possible.†

Specific gravity.

493. The specific gravity of atmospheric air, at mean temperature and pressure, that is, the thermometer being at 60°, and the barometer at 30 inches, is, usually considered as = 1. It is about 828,59 times as light as its bulk of water, 100 cubical inches weighing 30,5 grains.

Chemical effects dependant on oxygen.

494. Atmospheric air has already been stated to consist essentially of oxygen and nitrogen gases (490); but whether it should be considered a mere mixture or a chemical compound seems a question not easily decided. The former of these gases seems to be the only ingredient on which the effects of the air, as a chemical agent, depend. Hence combustible bodies burn in atmospheric air, only in consequence of the oxygen gas which it contains; and when this is exhausted, air is no longer capable of supporting combustion. Its analysis is satisfactorily demonstrated by the action of heated mercury, but the process is extremely tedious. (See LAVOISIER's *Elements*, *chap*. iii.)

Lavoisier's experiments.

By exposure, during 12 days to mercury heated in a retort, a given quantity of atmospheric air was found to be diminished in bulk, and to have lost its property of supporting combustion. The mercury was changed into red scaly particles, and it had acquired an increase of weight. When these red particles were submitted to heat, in a retort, oxygen gas was evolved equal in bulk to what the air had lost in the first part of the experiment.

495. If a little sulphur or phosphorus be burnt in a jar of atmospheric air, instead of oxygen gas (262) the combustion will be less vivid, and will cease sooner. The remaining air will not support combustion, and will be found to be nitrogen gas.

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* See Camb. *Mechanics*, page 351.

† See Camb. *Mechanics*, page 403.

Eudiometry.

There are various ways of learning the proportion which the oxygen bears to the nitrogen; and as the relative fitness of the air for breathing has sometimes been considered as depending upon the quantity of oxygen contained in a given volume, the instruments used in these experiments have been called *eudiometers*.

496. From facts already stated it is obvious, that if atmospheric air, mixed with a certain quantity of hydrogen, be detonated by the electric spark (338) the absorption will be proportionate to the quantity of oxygen present.

When 100 measures of pure hydrogen are mixed with 100 of pure oxygen, the diminution of bulk after detonation will amount to 150 parts, that is, one volume of oxygen requires for its saturation two of hydrogen. If we introduce into the graduated detonating tube (fig. 88) 300 measures of common air, and 200 of pure hydrogen, there will remain, after detonation 305 measures; so that 195 measures will have disappeared, of which one-third may be estimated as pure oxygen; hence 300 parts of air have thus lost 65 of oxygen, or about 21 *per cent.*

497. The general rule, therefore, for estimating the purity of air by hydrogen gas may be stated as follows:—Add to 3 measures of the air under examination 2 measures of pure hydrogen; detonate; and, when the vessel has cooled, observe the absorption; divide its amount by 3, and the quotient is the quantity of oxygen.

Upon the same principle, detonation of mixtures of oxygen and hydrogen is often resorted to, with a view of ascertaining the purity of those gases. Thus, suppose 100 measures of oxygen, and 300 of hydrogen, to be reduced by detonation to 130, the whole diminution will be = 270, which, divided by 3, gives 90 for the quantity of oxygen; so that it contained 10 *per cent.* of some gas, not condensable by detonation with hydrogen.

To ascertain the purity of hydrogen, it may be detonated with excess of pure oxygen. Thus, if we add 100 of pure oxygen to 100 of hydrogen, and detonate, there will be a diminution equal to two-thirds, or 150 parts if the hydrogen be pure. If, however, we suppose 100 of pure oxygen, mixed with 100 of hydrogen, to produce, after detonation, a residue of 80 measures; the diminution will then have been only 120 measures, of which two-thirds, or 80 measures, are hydrogen; so that the inflammable gas will have contained 20 *per cent.* of some other gaseous body, not condensable by detonation with hydrogen.

Eudiometer of Volta.

498. This mode of ascertaining the purity of atmospheric air was first resorted to by Volta, and it is susceptible of great accuracy, since pure hydrogen and pure oxygen are easily procured. An improved detonating tube for these purposes has been described by M. Gay-Lussac, *Annales de Chim. et Phys.* IV.

188.[*] Several new Eudiometers have been described by Professor Hare in the *American Jour. of Science*, Vols. II and X.

Of Scheele.

499. Scheele, in his eudiometrical experiments, employed *sulphuret of potassa*, the solution of which rapidly absorbs oxygen, as may be shown by agitating it with some atmospheric air, in a graduated glass tube. Or take two tubes, each a few inches long, closed at one end, and divided into 100 aliquot parts. Fill the one with atmospherical air, the other with oxygen gas, and invert them in two separate cups, filled with a solution of sulphuret of potash. The sulphuret will ascend gradually within the tube of common air, till, after a few days, about four-5ths of its original volume will remain; but, in that containing oxygen, it will ascend much higher, and, if the gas be pure, will even absorb the whole.

The explanation of this fact is, that liquid sulphuret of potash has the property of absorbing oxygen, but not nitrogen. It therefore acts on atmospheric air, only as long as any oxygen gas remains, and may be employed as a means of ascertaining the quantity of this gas in the atmosphere at different times and at distant places. H. 1. 289.

Of Hope.

500. The best instruments for these experiments are the eudiometric tubes of Dr Hope (NICHOLSON'S *Journal*, Vol. iv.)

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[*] In the eudiometer of Dr Ure, the atmospheric air, the most elastic and economical of all springs, is employed to receive and deaden the recoil. This eudiometer consists of a glass syphon (fig 107), having an interior diameter of from 2-10ths to 4-10ths of an inch. Its legs are of nearly equal length, each being from six to nine inches long. The open extremity is slightly funnel-shaped, the other hermetically sealed; and has inserted near it, by the blow-pipe two platina wires. The outer end of the one wire is incurvated across, so as nearly to touch the edge of the aperture; that of the other is formed into a little hook, to allow a small spherical button to be attached to it when the electrical spark is to be transmitted. The two legs of the syphon are from one fourth to one-half inch asunder. The sealed leg is graduated by introducing successively equal weights of mercury from a measure glass tube. Seven ounces troy and 66 grains, occupy the space of a cubic inch; and 34 1-4 grains represent $\frac{1}{100}$ part of that volume. The other leg may be graduated also, though this is not necessary.

To use this instrument, we first fill the whole syphon with mercury or water; the open leg is then plunged into a pneumatic trough, and any convenient quantity of the gases are introduced from a glass measure tube containing them in determinate proportions. Applying the finger to the orifice we next remove it from the trough, like a simple tube, and by a little dexterity transfer the gas into the sealed leg of the syphon. When we conceive enough has been passed up, the finger is removed and the mercury brought to a level in both legs, either by the addition of a few drops, or by the displacement of a portion, by thrusting down into it a small cylinder of wood. We now ascertain, by careful inspection, the volume of included gas. Applying the forefinger again to the orifice, so as also to touch the end of the platina wire, we then approach the pendent ball or button to the electrical machine, and transmit a spark, but a slight push or pressure on the tip of the finger is felt, even when the gas is in considerable quantity and of a strongly explosive power. After explosion on gradually sliding the finger to one side and admitting the air, the mercurial column in the sealed leg will rise more or less above that in the other. The equilibrium is then restored by adding mercury, when we read off, without any reduction, the true resulting volume of gas. As two inches or more of air should always be left between the finger and the mercury, this atmospheric column serves as a perfect recoil spring, enabling us to explode very large quantities without danger.

We may analyze the residual gaseous matter, by introducing, either a liquid or solid reagent. We first fill the open leg nearly to the brim with quicksilver, and then place over it the substance whose action on the gas we wish to try. If liquid, it may be passed round into the sealed leg among the gas; but if solid the gas must be brought round into the open leg, its orifice having been previously closed with a cork or stopper. After a proper interval the gas having been transferred back into the graduated tube, the change of its volume may be accurately determined.—Ure's *Dict.* 440—*Edin. Phil. Trans.* 1818.

and Dr Henry (*Elements*, Vol. i. p. 290). The former, fig. 104, consists of a small bottle, holding about three ounces, into which the glass tube *a*, which holds precisely a cubic inch, and is divided into 100 equal parts, is carefully fitted by grinding. It also has a ground stopper at *b*. To use it, the phial is filled with the solution of the alkaline sulphuret (which is best prepared by boiling a mixture of quicklime and sulphur with water, filtering the solution, and agitating it for some time in a bottle half filled with common air,) and the tube *a*, containing the air to be examined, fitted into its place. After inverting and agitating the instrument, the stopper *b* may be opened under water, and the absorption is shown by the rise of the fluid in the tube. For the glass bottle Dr Henry substituted the elastic gum bottle *b*, fig. 105, in the neck of which a short piece of glass tube is secured, into which the tube *a* is fitted by grinding.

Of Pepys.

In the *Philosophical Transactions* for 1807, Mr Pepys has described a modification of this Eudiometer, which may be often advantageously employed in delicate experiments, and by which an absorption of only $\frac{1}{1000}$ part of the gas under examination may be measured.

Of Priestley.

501. When nitric oxide gas and atmospheric air are mixed, there is a production of nitrous acid, in consequence of the union of oxygen with the oxide (430); and if the mixture be made over water, an absorption, proportional to the quantity of nitrous acid formed, ensues. Upon this principle nitric oxide may be used in eudiometrical experiments, and, if proper precautions be attended to, it furnishes tolerably accurate results. Dr Priestley and Mr Cavendish (*Phil. Trans.* 1783,) availed themselves of this mode, and Mr Dalton has offered some remarks upon its relative accuracy (*Phil. Mag.* Vol. xxviii.) The most certain results are obtained by adding to 100 parts of the atmospheric air, previously introduced into a small beer glass, an equal volume of nitric oxide gas. The mixture may be gently agitated, and in two or three minutes, carefully decanted into a graduated tube, when it will be found that 84 measures, have disappeared; of which one-fourth, or 21 measures, are oxygen.

Of Davy.

Sir H. Davy suggested the use of a solution of sulphate of iron, impregnated with nitric oxide gas, for the absorption of oxygen; it may be employed in the same way as the alkaline sulphuret (500.)

502. If a stick of phosphorus be confined in a portion of atmospheric air it will slowly absorb the oxygen present. The rapid combustion of the same substance may also be conveniently resorted to. For this purpose a small piece of phosphorus may be introduced into the bulb of the tube *a*, fig. 106, containing a given measure of the air to be examined. confined over mercury, which, to prevent loss by expansion, should be suffered to occupy about half the tube, or to stand at *b*. The

phosphorus may then be inflamed in the tube; and when the combustion is over, and the tube cold, the residuary air may be transferred for measurement. These eudiometrical methods were used by Lavoisier, Berthollet, and Seguin (*Annales de Chimie*, tom ix. and xxxiv.) and are both susceptible of accuracy, and a loss of volume = 21 *per cent.* of the atmospheric air will invariably be found to have occurred.[*] Of Lavoisier, &c.

503. By experiments thus conducted, it has been found that the composition of the atmosphere is extremely uniform in all parts of the world, and at all heights above its surface; and that it consists of,

	By Measure.	By Weight.
Oxygen	21	23,3
Nitrogen	79	76,7
	100	100,0

Though these are the essential component parts of atmospheric air, it contains other substances, which, however, may be regarded as adventitious, and the quantity of which is liable to vary: of these, carbonic acid and aqueous vapour are the most important and constant. The quantity of the former may usually be considered as amounting to less than 1 *per cent.* Carbonic acid in air.

504. The presence of aqueous vapour in the atmosphere is shown in a variety of ways, but most easily by exposing to it certain deliquescent substances which liquefy and increase in weight, in consequence of its absorption; and as the gases in general, unless artificially dried, also contain vapour of water, it is necessary, in delicate experiments, and in ascertaining their specific gravity, to take this ingredient into the account, or to separate it by proper means, such as exposure to very deliquescent substances, among which fused chloride of calcium is especially useful. Water in air.

The quantity of water contained in air and gases is subject to variation. From the experiments of Saussure and Dalton, it appears that 100 cubic inches of atmospheric air at 57°, are capable of retaining 0,35 grains of watery vapour; in this state the air may be considered at its maximum of humidity: it would also appear that all the gases take up the same quantity of water when under similar circumstances, and that it consequently depends, not upon the density or composition, but upon the bulk of the gaseous fluid.

We are indebted to Mr Dalton for some valuable information respecting the state in which water exists in air; from which it may be concluded that it is in the state of vapour, forming an independent atmosphere, mixed, but not combined with, or dissolved in the air.

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[*] Since the discovery of Professor Dœbereiner, that platinum sponge causes the union of hydrogen and oxygen gases (336), it has been applied to the purposes of Eudiometry. The finely divided platinum being formed into small balls with clay, and passed up into small graduated tubes containing the air to be examined, over mercury. (See, Boston Jour. of Philosophy &c. Vol. i. p. 548, ii. 280, iii. 13.)

Hygrometers.

505. *Hygroscopes* and *Hygrometers* are instruments which show the presence of water in the air, its variation in quantity, and its actual quantity existing in a given bulk of air at any given time. Saussure employs a human hair, which, by its dilatations and contractions in moisture and dryness, is made to turn an index; Deluc used a thin strip of whalebone in the same way; Wilson employed a rat's bladder, which is filled with mercury, and tied on a large thermometer tube, and by its dilatation and contraction causes the mercury to fall and rise in the tube, and thus to indicate changes in the moisture of the air. Mr Daniell has constructed a hygrometer, which shows the constituent temperature of the moisture in the atmosphere, by its precipitation upon a cold surface; comparing this with the temperature of the atmosphere, the difference furnishes a datum for calculating the quantity of vapour in a given quantity of air, and affords indications usefully applicable to predicting change of weather. See *Quarterly Jour. of Science*, Vols. viii. ix. x.

SECTION III. *Sulphur.*

Properties.

506. SULPHUR, or brimstone, is a brittle substance, of a pale yellow colour; insipid and inodorous, but exhaling a peculiar smell when heated. Its specific gravity is 1,990.* It becomes negatively electrical by heat and by friction.

Sulphur is principally a mineral product, and occurs crystallized, its primitive form being a very acute octoëdron with an oblique base. Its crystals are in a high degree doubly refractive.

Action of heat.

507. When sulphur is heated to about 180°, it volatilizes, and its peculiar odour is strong and disagreeable; at 225° it liquefies; between 350° and 400° it becomes viscid, and of a deep brown colour; and at about 600° it quickly sublimes. When slowly cooled after fusion, it forms a fibrous crystalline mass. It suffers no change by exposure to air, and is insoluble in water.

Crystallizes.

508. Sublimed sulphur, when examined by a microscope appears composed of minute crystals; it is always slightly sour, and hence, for some pharmaceutical purposes, is directed to be washed in hot water.

How obtained.

509. Massive sulphur is chiefly brought to this country from Sicily; it occurs native, and is found associated with sulphate of lime, sulphate of strontia, and carbonate of lime. Its colour is various shades of yellow, and the transparent crystals are doubly refractive; it is not uncommon among volcanic products.

510. Roll-sulphur is chiefly obtained from sulphuret of copper in this country (Eng.); which is roasted and the fumes receiv-

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* Sp. gr. of sulphur vapour $\left\{\begin{array}{l}1{,}1111 \text{ air} = 1\\ 1, \text{oxygen} = 1.\end{array}\right\}$ T.

ed into a long chamber of brick-work, where the sulphur is gradually deposited: it is then purified by fusion, and cast into sticks. In this state, if grasped by the warm hand, it splits with a crackling noise.

511. Though it had already been suspected, (chiefly from the experiments of M. Berthollet, jun.) that sulphur contains hydrogen, yet the first unequivocal evidence of the fact was furnished by Sir H. Davy. A bent glass tube, having a platinum wire hermetically sealed into its upper extremity, was filled with sulphur. The sulphur was melted by heat; and a proper connection being made with the Voltaic apparatus of 500 double plates, each six inches square and highly charged, a most intense action took place. A very brilliant light was emitted; the sulphur soon entered into ebullition; elastic matter was evolved in great quantities; and the sulphur, from being a pure yellow, became of a dark reddish brown tint. The gas was found to be sulphuretted hydrogen, or hydrogen gas holding sulphur in solution; and its quantity, in about two hours, was more than five times the volume of the sulphur employed. Contains hydrogen,

Another proof of the presence of hydrogen in sulphur is derived from the action of potassium; for these two bodies combine with great energy, and evolve sulphuretted hydrogen, with intense heat and light.

Lastly, when dry sulphur is melted in dry oxygen gas, Sir H. Davy is of opinion, that, besides sulphuric acid, a portion of water is also formed; but he is still doubtful whether the hydrogen in sulphur can be considered as any thing more than an accidental ingredient. This view of the subject is embraced, also, by Berzelius, who found by heating sulphur with oxide of lead, that the quantity of water produced is much too minute to indicate any definite proportion of hydrogen in sulphur.

512. Another ingredient of sulphur, it appeared probable from the experiments of Sir H. Davy, is oxygen. For potassium, after being made to act on sulphuretted hydrogen gas, evolved less hydrogen from water, than it ought to have done. It has since, however, been proved by Gay-Lussac, that, when all sources of fallacy are avoided, a given weight of potassium, which has been exposed to sulphuretted hydrogen, separates exactly the same volume of hydrogen gas from water, as an equal weight of recent metal. Potassium, therefore, acquires no oxygen from the sulphur, which is contained in sulphuretted hydrogen. H. 1. 373. probably oxygen.

513. For some pharmaceutical purposes sulphur is precipitated from its alkaline solutions, as from sulphuret of potassa by an acid, and, when washed and dried, is in the form of a yellowish-grey impalpable powder; it is the *milk of sulphur* and *precipitated sulphur* of the *Pharmacopœia.* Dr Thomson considers it as a compound of sulphur and water.—*System of Chem.* Vol. i. 285. Milk of sulphur.

Exp. To a portion of water saturated with sulphurous acid gas add a little oxide of manganese, a substance that contains much oxygen loosely combined, the pungent smell of the water, and the other characteristics of sulphurous acid will soon disappear. H. 1. 385.

Union with ammonia. 523. When sulphurous acid is mixed in equal volume with ammonia, a yellowish salt is produced, which is a *sulphite of ammonia*, and which consists of 32 sulphurous acid + 17 ammonia. When formed by saturating liquid ammonia with sulphurous acid, it crystallizes in four and six-sided prisms, soluble in their own weight of water and having an acrid taste. It is deliquescent, and becomes a *sulphate* by exposure to air.

Anhydrous sulphurous acid. 524. *Anhydrous Sulphurous Acid*, has been obtained by M. Bussy of Paris who has given the following directions for its preparation.

Process for obtaining. 525. Equal parts of mercury and sulphuric acid are put into a small matrass, which is connected with a receiver having a long tube passing into a small flask. The receiver is to be surrounded with melting ice, in order to condense the water which passes over with the gas. The tube is filled with fragments of fused muriate of lime, to absorb any aqueous vapour which may not have been condensed in the receiver. The flask should also be surrounded with melting ice or a freezing mixture. As the acid passes over it is condensed in the flask and appears in the liquid state.

Properties. 526. When obtained in this manner the liquid sulphurous acid has the following properties. It is colourless, transparent, of the specific gravity of about 1,45, and it boils at the temperature of 14° F.

527. When poured on the hand it produces a sharp cold, and completely evaporates. If poured, drop by drop, into water, at the ordinary temperature it occasions a species of effervescence, owing to the volatilization of part of the acid, and the surface of the water is covered with ice.

With this acid Mr Bussy has found it easy to freeze mercury. The mercury is to be placed in a watch glass on the plate of the air pump, and the acid being added the receiver is quickly placed over it and exhausted (140). From 20 to 30 grains of mercury and as much acid may be employed.

Mr Bussy has also succeeded in freezing ether and alcohol; small balls being filled with these liquids, which after being surrounded with cotton and moistened with the sulphurous acid, were placed under the receiver of the air pump, the acid being rapidly evaporated.

528. It has also been applied to the liquefaction of chlorine and several other gases. (See *Boston Journal of Philosophy*, Vol. ii. 359.)

Sulphuric acid. 529. *Sulphuric Acid.*—This body was formerly obtained by the distillation of green vitriol, and called *oil of vitriol*. It is now procured in this country by burning a mixture of about 8 parts of sulphur and 1 of nitre in close leaden chambers containing water, by which the fumes produced are absorbed, and by evaporation the acid is procured in a more concentrated state. This improved method of preparing sulphuric acid was invented by Dr Roebuck, about the year 1746.—PARKES's *Chemical Essays*, Vol. ii.—Brande's *Prefatory History of Chemistry*, Vol. i. p. 36. Sulphuric acid has been known ever since the time of Basil Valentine, who appears to have discovered it about the close of the 15th century.

Properties.

530. Sulphuric acid, as usually met with, is a limpid colourless fluid, having a specific gravity of 1,80; it boils at 620°, and freezes at 15°, contracting at the same time considerably in its dimensions. But the temperature at which the diluted acid congeals is singularly modified by the quantity of water which it contains. At the specific gravity of 1,78 it freezes at about 40°; but if the density be either increased or diminished, a greater cold is required for its congelation (KEIR, *Irish Phil. Trans.* iv. 88.) Its boiling point diminishes with its dilution; acid of the specific gravity of 1,78, boils at 435°, and acid of the specific gravity of 1,650 boils at 350°.—DALTON's *Chem. Phil.* ii. 404.

It is acrid and caustic, and when diluted with water, produces a very sour liquid. It rapidly absórbs water from the atmosphere. When mixed suddenly with water, (42) considerable heat is produced. Four parts, by weight, of concentrated sulphuric acid, and one of water, when mixed together, each at the temperature of 50° Fahrenheit, have their temperature raised to 300°. The greatest elevation of temperature, Dr Ure finds to be occasioned by the sudden mixture of 73 parts by weight of strong sulphuric acid with 27 of water. This rise of temperature takes place because the affinity or capacity of the compound of acid and water for caloric, is less than that of the acid and water separately. A diminution of bulk also ensues; one measure of acid and one of water not occupying the space of two measures, but about $\frac{1}{15}$th less. H.

Imbibes moisture.

531. Even a boiling temperature, when it is concentrated, does not prevent its taking up moisture from the air; hence it cannot be concentrated so well in an open as in a close vessel, on which account retorts, of glass or platinum, are used for the last stage of its concentration by the manufacturers.

532. It chars animal and vegetable substances, and is apt to acquire a brown tinge from any small particles of straw, resin, or other matters that may accidentally have fallen into it.

Composition.

533. In sulphuric acid 1 proportional of sulphur = 16, is combined with 3 of oxygen = 24, and, consequently, *dry* sulphuric acid is correctly represented by 16 + 24 = 40; but it only exists in this state (like the nitric and chloric acids) when united with

bases, and in its ordinary state contains water, and may, therefore, be called *hydrated sulphuric Acid.* It has been found by experiment, that 100 parts of sulphuric acid, specific gravity 1,85, contain 18,5 of water; consequently, it may be looked upon as composed of 1 sulphur + 3 oxygen + 1 water:

Or of 16 sulphur
24 oxygen
9 water
——
49 number for liquid sulphuric acid.

100 Parts of liquid sulphuric acid, of the specific gravity of 1,3530, contain 37,5 parts of dry sulphuric acid; or 46 of liquid acid, of the specific gravity 1,85.

The following table exhibits the proportions of the elements of sulphuric acid in 100 parts of real acid, deduced from different experiments.

	Sulphur.	Oxygen.
From the experiments of Berthollet . .	43,28 . .	56,72
Klaproth . . .	42,20 . .	57,80
Bucholz . . .	42,50 . .	57,50
Berzelius . .	39,92 . .	60,08
Proportions admitted by Dr Wollaston . .	40,00 . .	60,00

H. 1. 381.

Method of determining the strength of sulphuric acid.

534. The strength of sulphuric acid is best judged of by saturating a known quantity with an alkali, and it may be assumed as sufficiently correct, that 100 grains of dry sub-carbonate of soda neutralize 92 grains of pure liquid sulphuric acid; or that 100 grains of the acid require 108, or 108,5 of the subcarbonate for saturation. H. Mr Dalton has published (*New System of Chemical Philosophy*, Vol. ii. p. 404,) a Table, exhibiting the specific gravity and boiling point of the acid of various strengths.[*] See *Tables.*

Dr Ure also has given several valuable tables relating to this subject, in his *Experiments to determine the Law of Progression, followed in the Density of Sulphuric Acid at different Degrees of Dilution* (*Quarterly Journal of Science and the Arts*, Vol. iv. p. 114. An extremely useful table of this kind will also be found in Mr Parkes's *Essays* above quoted (Vol. ii. p. 444.)

Effect of chlorine.

535. Sulphurous acid gas is condensed into Sulphuric acid by admixture with chlorine gas; but not unless the gases are in contact with water. In the latter case, the hydrogen of the water

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[*] It is sometimes of importance to the chemical artist to know the proportion not of *real acid*, but of *acid of commerce*, in diluted sulphuric acid of different specific gravities. An approximation to the true proportion may be obtained, by increasing the numbers indicating the real acid, one fourth. For example, acid of the specific gravity 1,200, contains (according to the table of Mr Dalton) 20 per cent. of real acid, which increased one fourth, gives 25 per cent. of acid, of sp. gr. 1, 849. H.

unites with the chlorine, and the oxygen with the sulphurous acid.

Not affected by dry nitrous gas.

536. Dry nitrous acid gas is also inefficient on dry sulphurous acid; but when placed in contact with a small quantity of water, all these bodies act mutually and rapidly on each other; the nitrous acid gas yields a portion of its oxygen to the sulphurous acid, from whence result nitrous gas and sulphuric acid, which, both combining with water, form white flakes upon the inside of the balloon. These flakes are made up of congeries of small crystalline needles. Water, brought into contact with these crystals, dissolves the sulphuric acid, and the nitrous gas is liberated with effervescence. By means, therefore, of a small quantity of nitrous gas, we may transform a large quantity of sulphurous acid into sulphuric acid, provided the acid gas be mingled with half its volume of oxygen, or with an equivalent quantity of atmospheric air. The phenomena are beautifully exhibited by admitting, into an exhausted and dry glass balloon, first 30 measures of sulphurous acid, next 15 of oxygen, and then 5 of nitrous gas. No perceptible change takes place, till a little water is introduced, sufficient to moisten the inside of the vessel, when the small quantity of red nitrous acid, formed on adding the nitrous gas, disappears, and composes the crystalline substance already described. When those crystals have been deposited on the inside of the balloon, and a small quantity more of water is admitted, there is an immediate effervescence from the escape of nitrous gas, which, meeting with oxygen gas, again becomes nitrous acid, and this, acting upon the sulphurous acid, the same combinations ensue as before, and may be repeated as long as sufficient sulphurous acid and oxygen remain.

Ex.

Theory of the formation of sulphuric acid.

537. It is by a series of operations of this kind, that the formation of sulphuric acid is effected in the ordinary process for preparing it. The nitric acid, present in the salt-petre, abandons part of its oxygen to one portion of the sulphur, which, becoming sulphuric acid, unites with the potash of the nitre. At the same moment nitrous gas is set at liberty, which, with the oxygen present in the air of the chamber, composes nitrous acid gas. Another portion of sulphur is converted into sulphurous acid, which becomes sulphuric acid by depriving the nitrous acid of oxygen, the latter acid being brought back to the state of nitrous gas. This gas, absorbing the atmospheric oxygen, again becomes nitrous acid, which changes a fresh portion of sulphurous into sulphuric acid. This theory was first suggested by M. M. Clement and Desormes. It has since been modified by Gay-Lussac, who supposes that nitrous acid, and not nitrous gas, is disengaged from nitrate of potash. But even if this be admitted, the subsequent steps of the process are still explicable on the original theory, which satisfactorily explains why so small a proportion of nitre as one eighth is adequate to the conversion of sulphur into sulphuric acid, though, capable

of supplying only a very small share of the oxygen essential t this change.* H. 1. 386.

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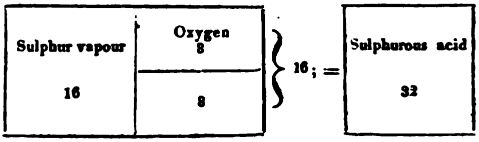
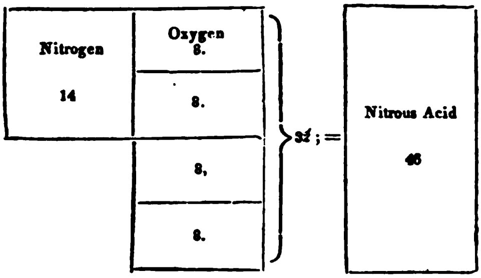
* The formation of sulphuric acid by the combustion of sulphur and nitre has been illustrated Mr Brande as follows.

Sulphurous acid consists of

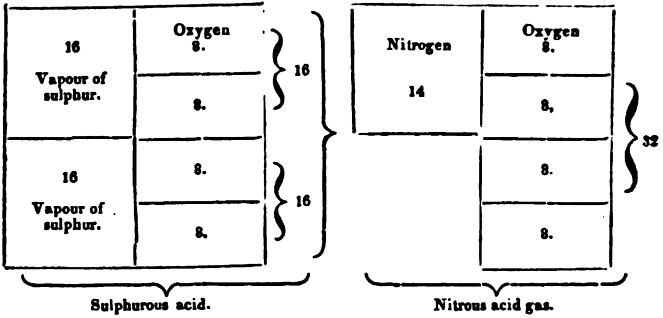


And nitrous acid contains

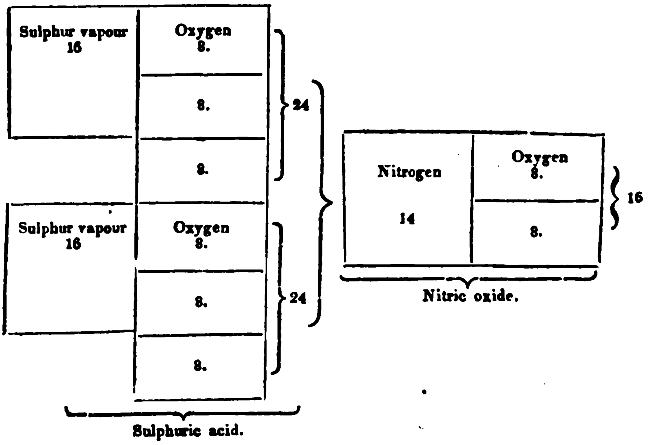


hence every *two* portions of sulphurous acid require *one* of nitrous acid, which transfers *two* of oxygen, and passes back into the state of nitric oxide, sulphuric acid being, at the same time, produced.

The gases, therefore, before decomposition, may be thus represented:



And after decomposition as follows:



Analysis of sulphuric acid.

538. The decomposition of sulphuric acid may be effected by passing it through a red-hot platinum tube, when it is resolved into sulphurous acid, oxygen and water.

When heated with charcoal, sulphuric acid gives rise to the production of carbonic and sulphurous acids; with phosphorus it produces phosphoric and sulphurous acids; and, with sulphur, sulphurous acid is the only product. It is decomposed by several of the metals, which become oxidized, and evolve sulphurous acid, as shown in the production of this acid, by boiling sulphuric acid with mercury (525), tin lead, *&c.*

Uses.

539. Sulphuric acid is largely consumed in a variety of manufactures. It is used by the makers of nitric, muriatic, citric, and tartaric acids; by bleachers, dyers, tin-plate makers, brass-founders and gilders. For these purposes it is generally sufficiently pure as it comes from the wholesale manufacturer; but, as traces of lead, lime, and potassa, are usually found in it, it often requires to be purified by distillation for the use of the experimental chemist.

Distillation of sulphuric acid;

The distillation of this acid in glass retorts requires some precaution, in consequence of the violent jerks which the production of its vapour occasions, and which often break the vessel; this may be prevented by putting some strips of platinum into the acid; it then boils quietly, and it is only necessary to take care that the neck of the retort and the receiver are not broken in consequence of the high temperature of the condensing acid.

Purification of.

If the acid of commerce contain dissolved sulphate of lead, it becomes turbid on dilution, so that its remaining clear when mixed with water, is some proof of its purity, as far at least as lead is concerned.

To purify sulphuric acid, it must be distilled in a glass retort, placed in the sand-bed of a reverberatory furnace. This process requires considerable care. But to those who have sufficient experience in chemical operations, the following instructions may be useful; especially as it is indispensable, in all experiments of research, to employ an acid purified by distillation.

The furnace in which this process is conducted, should have a contrivance for supporting a sand-bath within it at a proper height; and an opening in the side, for transmitting the neck of the retort. The retort must be coated with clay and sand over its whole body, and also over that part of the neck which is exposed to the fire. It is then to be placed, the coating being previously dry, in the sand-bath, about one half filled with sulphuric acid; and a receiver must be applied, but not luted on. The fire must now be lighted, and raised with extreme caution. The first portion that comes over, amounting to about one sixth, consists chiefly of water, and may be rejected. This is followed by the concentrated acid; and, at this period, there is great risk that the neck of the retort will be broken, by the contact of the condensed acid, which has a very high temperature, and which frequently cracks the glass, as effectually as the application of a red-hot iron. The fire must be regulated by the register door of the ash pit, so that several seconds may elapse between the fall of the drops into the receiver. The process may be continued as long as any acid is condensed. The retorts employed for this purpose, should be most attentively annealed.

540. The difficulty of rectifying sulphuric acid is much diminished by using a retort of the capacity of from two to four quarts, when a pint of the acid is employed, and by connecting its neck with the receiver by means of an adopter three or four feet long. The retort may be set over a charcoal fire, and the flame made to play gently on its bottom. No luting is to be employed, and the receiver is to be surrounded with cold water. With this arrangement, and a cautious regulation of the heat, Dr Ure finds that sulphuric acid may be distilled without much risk, in a continuous gentle stream.

541. Sulphuric acid may be less perfectly purified by diluting it with an equal weight of water, allowing the impurities to settle, decanting the clear liquor and evaporating it to the proper degree in a glass retort. H. 1. 379.

Glacial sulphuric acid.

542. When sulphuric acid was procured by the distillation of green vitriol, it was frequently observed that a portion concreted into a white mass of radiated crystals. The same substance has also been remarked as occasionally formed in the acid of the English manufacturers. It has been called *glacial* or *fuming sulphuric acid*, and is by Dr Thomson considered as the pure or anhydrous acid; it appears, however, probable, that it consists of sulphuric acid, combined with a portion of sulphurous acid.—See *Sulphate of Iron.*

543. It has long been an object with the manufacturer to obtain sulphuric acid without the aid of nitre, and a patent has been obtained for a process of this kind, invented by Mr Hill. It consists in submitting coarsely-powdered iron pyrites (sulphuret of iron,) to a red heat, in cylinders communicating with a leaden chamber containing water; the sulphur, as it burns out of the pyrites, appears at once to pass into the state of sulphuric acid.

544. *Native Sulphuric Acid* has been found by Professor Baldassari, in the cavities of a small volcanic hill, called Zocolino, near Sienna, and by M. Humboldt in the water of the river Vinagre in the Andes of Popayan. (See *Boston Jour. of Philos.* Vol. 11. p. 460).

Hypo-sulphurous acid.

545. *Of Hypo-sulphurous Acid.*—This acid exists only in combination with salifiable bases, forming compounds which were first examined in 1813 by Gay-Lussac, and were called by him *sulphuretted sulphites.* Besides other methods of preparing these salts, he found that they might be obtained by digesting the solution of a sulphite with sulphur, an additional quantity of which might thus be made to combine with the sulphurous acid. It had also been long ago observed by

Mr Higgins of Dublin. that liquid sulphurous acid dissolves iron without effervescence; and Berthollet afterwards showed that in this case the iron is oxidized at the expence of the sulphurous acid, and that sulphur is disengaged. which immediately unites with the sulphite of iron, forming a sulphuretted sulphite. Dr Thomson appears to have been the first who took a just view of these phenomena. The new compound he found to be a neutral salt, containing a peculiar acid of sulphur, to which he gave the name of *hypo-sulphurous acid*, and to its compounds that of *hypo-sulphites*. These compounds have been since examined with great ability by Mr Herschell, who has not, however, succeeded completely in his attempt to exhibit the acid in a separate state; nor indeed does it appear capable of existing permanently when uncombined with a base. From the experiments of Dr Thomson and Mr Herschell, it may be inferred to be a compound of 1 atom of sulphur + 1 atom of oxygen, and its representative number will be 16 + 8 = 24.

Composition.

Hypo-sulphuric acid.

546. *Hypo-sulphuric Acid.*—This acid was discovered by Welter and Gay-Lussac. Their process for forming it consists in passing a current of sulphurous acid through water, in which finely powdered peroxide of manganese is kept mechanically suspended. There is immediately produced a perfectly neutral solution. consisting of hypo-sulphate and common sulphate of manganese. When the solution is sufficiently concentrated, pure barytes is added to the previously heated liquor, and agitated along with it, taking care to employ an excess of the earth. All the oxide of manganese is thus separated; and, sulphate of barytes being insoluble. the filtered liquor contains only the hypo-sulphate of barytes and also the redundant portion of that earth. The latter is to be separated by a stream of carbonic acid, and subsequent ebullition to expel any excess of carbonic acid. The hypo-sulphate is then to be crystallized, dissolved in water, and decomposed by just the quantity of sulphuric acid, which is required to precipitate the barytes. The filtered liquor is to be concentrated, by exposing it under the exhausted receiver of an air-pump. along with a vessel of sulphuric acid, till it has attained the density of 1,347. If continued to be exposed. it is resolved into sulphurous acid which exhales, and sulphuric acid which remains liquid. H. 1. 389.

Not acted upon by oxygen, &c.

547. Oxygen gas, atmospheric air, chlorine, concentrated nitric acid, and red sulphate of manganese, are all inert on it at common temperatures. Zinc is dissolved by it, and hydrogen gas is disengaged by the decomposition of water, and their remains in solution hypo-sulphuric acid combined with oxide of zinc. It completely saturates salifiable bases. and affords neutral and soluble compounds with barytes, strontites, lime, and protoxide of lead; whereas sulphuric acid yields insoluble compounds with all those bases. At common temperatures these salts are permanent. but, when heated sulphurous acid escapes, and they pass to the state of sulphates, which are still neutral.

Composition.

548. Hypo-sulphuric acid has been inferred to be composed of 100 parts of sulphur + 125 oxygen, setting apart that which is in the water essential to its existence; or we may consider it as a compound of 100 parts of sulphurous acid + 125 of sulphuric. H. 390.

Iodo-sulphuric acid.

549. When sulphuric acid is dropped into a concentrated and hot solution of iodic acid, a peculiar compound is formed, which may be termed *iodo-sulphuric acid;* it is yellow, fusible, and crystallizes on cooling in rhomboids; at a higher temperature it partly sublimes, and is partly decomposed. Its precise composition is unknown.

Sulphate of ammonia.

550. *Sulphuric Acid and Ammonia—Sulphate of Ammonia*—may be obtained by passing ammonia into sulphuric acid; but it is usually prepared by saturating dilute sulphuric acid with *carbonate of ammonia*, or by decomposing muriate of ammonia by sulphuric acid. It is the *secret sal-ammoniac* of some old writers. This salt is important as a source of the muriate of ammonia, (477) which is obtained by sublimation from a mixture of common salt and sulphate of ammonia; by this process sulphate of soda is also formed.

Composition.

Sulphate of ammonia dissolves in twice its weight of water at 60°, and consists of 1 proportional of sulphuric acid = 40 + 1 proportional of ammonia = 17. Its number, therefore, is 57. By crystallization it affords six-sided prisms. Its taste is bitter and pungent. When heated, it melts and in part sublimes, ammonia is given off, and a *super-sulphate* remains, consisting of 2 proportionals of acid + 1 of alkali.

551. *Native Sulphate of Ammonia* is sometimes found in volcanic products; it occurs in stalactitic concretions of a whitish or yellowish colour, and covered with a white efflorescence.

Chloride of sulphur.

552. *Sulphur and Chlorine—Chloride of Sulphur.*—This compound was first described by Dr Thomson, in 1804 (NICHOLSON's *Journal*, Vol. vii.) When sulphur is heated in chlorine, it absorbs rather more than twice its weight of that gas. 10 grains of sulphur absorb 30 cubic inches of chlorine, and produce a greenish-yellow liquid, consisting of 16 sulphur + 36,0 chlorine, and represented, therefore by the number 52. It exhales suffocating and irritating fumes when exposed to the air. Its specific gravity is 1.6. It does not affect dry vegetable blues; but when water is present, it instantly reddens them, sulphur is deposited and sulphurous, sulphuric, and muriatic acids are formed in consequence of a decomposition of the water. It dissolves sulphur and phosphorus.

Iodide of sulphur.

553. *Sulphur and Iodine* readily unite and form a black crystallizable compound, resembling sulphuret of antimony, first described by M. Gay-Lussac.—*Annales de Chimie*, 91.

Sulphuretted hydrogen.

554. *Sulphur and Hydrogen—Sulphuretted Hydrogen gas—Hydrothionic acid.*—This gaseous compound of sulphur and hydrogen was discovered by Scheele in 1777. It may be obtained by presenting sulphur to nascent hydrogen, which is the

case when sulphuret of iron is acted upon by dilute sulphuric acid.

Process for obtaining.

The sulphuret of iron may be prepared in the following manner. A bar of iron is to be heated to a white or welding heat in a smith's forge, and, in this state, is to be rubbed with a roll of sulphur. The metal and sulphur unite. and form a liquid compound, which falls down in drops. These soon congeal; and the compound must be preserved in a well closed phial.* A portion of this may be introduced into a retort or gas bottle and diluted sulphuric acid poured upon it, as in the process for obtaining hydrogen gas (328).

It may also be conveniently obtained by heating bruised sulphuret of antimony in muriatic acid. To a mixture of powdered sulphuret of antimony (crude antimony of the shops) with 5 or 6 times its weight of muriatic acid (sp. gr. 1.160 or thereabouts) contained in a retort or gas bottle, apply the heat of a lamp. Sulphuretted hydrogen will be disengaged in great abundance.

Absorbed by water.

555. Sulphuretted hydrogen gas may be collected over water, though, by agitation, that fluid absorbs nearly thrice its bulk; it should be received into bottles provided with glass stoppers, and after filling them entirely with the gas, the stopper should be introduced.

Properties.

556. Its smell is extremely offensive, resembling that of putrefying eggs, or of the washings of a gun barrel, to which indeed it imparts their offensive odour. It exists in some mineral waters.

557. The specific gravity of sulphuretted hydrogen to hydrogen is as 17 to 1.† 100 cubic inches weigh 36 grains. It is inflammable, and during its slow combustion, sulphur is deposited, and water and sulphurous acid formed. It extinguishes flame.

558. It appears to be one of the most unrespirable of all the gases, for a small bird died immediately in air containing $\frac{1}{1500}$ of its volume of sulphuretted hydrogen; a dog perished in air mingled with $\frac{1}{800}$ and a horse in air containing $\frac{1}{250}$. (Thenard, i. 723.)

559. It tarnishes silver, mercury, and other polished metals, and instantly blackens white paint and solution of acetate of lead. By direct experiments, Dr Henry has found that one measure of this gas, mixed with 20,000 measures of hydrogen, or of carburetted hydrogen, or common air, produces a sensible discoloration of white lead, or of oxide of bismuth, mixed with water, and spread upon a piece of card.

Hydro-sulphuric acid of Gay-Lussac.

560. Water, saturated with this gas, reddens infusion of violets, in this respect producing the effect of an acid. From this and other properties, some of the German chemists have pro-

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* The sulphuret, prepared by melting iron filings with sulphur in a crucible, does not answer the purpose equally well, because the gas, which it affords, is mixed with a good deal of hydrogen gas.

† Sp. gr. 1,1805 air = 1, or 1,0625 oxygen = 1, atomic weight 2,125. T.

posed for it the name of *hydrothionic acid;* and Gay-Lussac has given it the very objectionable name of *hydro-sulphuric acid*, a term which would be much more properly applied to liquid sulphuric acid.

Solution.

561. The aqueous solution of sulphuretted hydrogen is transparent and colourless, but if exposed to air it deposits sulphur and the gas escapes. It is an exceedingly delicate test of the presence of most of the metals, with which it forms coloured precipitates.

562. Water impregnated with sulphuretted hydrogen, when exposed to the atmosphere, becomes covered with a pellicle of sulphur. Sulphur is even deposited when the water is kept in well-closed bottles.

563. On the addition of a few drops of nitric or nitrous acid to the watery solution sulphur is instantly precipitated. In this case the oxygen of the acid combines with the hydrogen of the gas, and the sulphur is separated. The gas itself, also, is decomposed when transmitted through sulphuric, nitric, or arsenic acids.*

Results of its detonation with oxygen.

564. When one volume of sulphuretted hydrogen, and 1,5 of oxygen are inflamed in a detonating tube, 1 volume of sulphurous acid is produced, and water is formed. Thus the sulphur is transferred to 1 volume of the oxygen and the hydrogen to the half volume. Sulphuretted hydrogen. therefore, consists of 16 sulphur + 1 hydrogen, and its number is 17. Sulphuretted hydrogen may also be decomposed by the Voltaic flame. in the apparatus shown at fig. 43, or by a succession of electric sparks. Its volume is unchanged, but the sulphur is thrown down.

Decomposed by chlorine and iodine.

565. Chlorine and iodine instantly decompose sulphuretted hydrogen; sulphur is deposited, and muriatic and hydriodic acids are formed. It is also decomposed by the metal potassium, which absorbs the sulphur and liberates pure hydrogen, when heated in the gas. Nitric acid poured into the gas occasions a deposition of sulphur, and nitrous acid and water are formed.

Inflamed by nitric acid.

566. Berzelius has found that when a few drops of fuming nitric acid are put into a flask filled with sulphuretted hydrogen, the hydrogen is oxidized by the nitric acid, and the sulphur is disengaged in a solid form. If the flask be closed by the finger, so that the gas which becomes heated cannot escape, its temperature is raised so much as to produce combustion with a beautiful flame, and a slight detonation which forces the finger from the mouth of the flask. This experiment may be made with safety in a flask containing four or five cubical inches of gas.

Exp.

Decomposed by nitric oxide, &c.

567. When sulphuretted hydrogen is mixed with its volume of nitric oxide over mercury, a diminution of bulk ensues, in consequence of the production of water; sulphur is deposited and nitrous oxide remains in the vessel.

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* Journ. of Science, &c. ii. 152.

568. When two volumes of sulphuretted hydrogen are mixed in an exhausted balloon with one of sulphurous acid, they mutually decompose each other, occasioning the production of water, and the deposition of sulphur; if the gases be perfectly dry, the action is slow.

569. It is decomposed, also, when long kept in a state of mixture with atmospheric air, the oxygen of which combines with the hydrogen, and forms water, while the sulphur is precipitated.

Absorbed by alkalies and earths.

570. Sulphuretted hydrogen is copiously absorbed by alkalies, and by all the earths excepting alumina and zirconia. This property affords a ready method of ascertaining its purity, for if it be agitated with a solution of potash, the unabsorbed residue will show the amount of the impurity, which is commonly hydrogen gas. Its alkaline and earthy combinations are termed *hydro-sulphurets*.. It unites with an equal volume of ammoniacal gas, or, if transmitted through the watery solution of that gas, it is rapidly absorbed, and the compound, which is very useful as a chemical test, has a yellow colour and a strong smell of sulphuretted hydrogen. H. 1. 433.

Hydrosulphuret of ammonia.

571. *Sulphuretted hydrogen and ammonia* readily unite in equal volumes, and produce *hydrosulphuret of ammonia*. At first white fumes appear, which become yellow, and a yellow crystallized compound results, consisting of 17 sulphuretted hydrogen, + 17 ammonia. It is of much use as a test for the metals, and may be procured by distilling at nearly a red heat, a mixture of 6 parts of slacked lime, 2 of muriate of ammonia, and 1 of sulphur.

572. Fig. 108, represents the disposition of the apparatus for this experiment: *a*, a small furnace; *b*, a tubulated earthen retort containing the above materials; *c*, an adapting tube; *e*, a glass balloon for condensing the vapour; *f*, a receiver; *g*, a bottle of water, into which the glass tube, issuing from the upper part of the receiver, *e*, is made to dip about half an inch.

The product in the bottle *f* may be mixed with the water in *g*, and the whole used for washing out the receiver *e*. In its concentrated state, this compound exhales white fumes, as was first remarked by Boyle, whence it was termed *Boyle's Fuming Liquor*, or *Volatile Liver of Sulphur*. It is a deep yellow liquid, smelling like a mixture of sulphuretted hydrogen and ammonia.

When kept in common white glass vessels it renders them brown or black, in consequence of its action on the oxide of lead which the glass contains.

Super-sulphuretted hydrogen.

573. *Super-sulphuretted Hydrogen.*—This compound was discovered by Scheele, and afterwards examined by Berthollet (Ann. de Chim. tom. xxv.) It is obtained when hydro-sulphuret of potash (formed by boiling the flowers of sulphur with liquid potash) is poured, by little and little, into muriatic acid.

A very small portion only of gas escapes; and while the greater part of the sulphur separates, one portion of it combines with the sulphuretted hydrogen; assumes the appearance of an oil; and is deposited at the bottom of the vessel. Or, dissolve sulphur in a boiling solution of pure potash; and into a phial containing about ⅓d its capacity of muriatic acid, of the specific gravity 1,07, pour about an equal bulk of the liquid compound. Cork the phial, and shake it; the hydroguretted sulphur, gradually settles to the bottom in the form of a brown, viscid, semifluid mass. Its properties are the following:

Properties.

574. Its taste and smell resemble those of putrid eggs, but are less offensive. Its precise specific gravity is unknown, but is heavier than water, and descends through it. It is inflammable and burns in the air with a smell of sulphurous acid.

If gently heated, sulphuretted hydrogen gas exhales from it; the bi-sulphuret loses its fluidity; and a residue is left, consisting merely of sulphur.

It combines with alkalies and earths; and forms with them a class of substances called hydroguretted sulphurets.

Composition.

575. It is constituted according to Mr Dalton, of two atoms of sulphur = 32, with one atom of hydrogen, and is represented by the number 33. It consists per cent. of

Sulphur	96.75
Hydrogen	3.25
	100. H. 1. 435.

576. *Sulphur and Nitrogen* do not form any definite compound, though the nitrogen evolved during the decomposition of certain animal substances, often seems to contain sulphur.

577. Sulphur, in its ordinary state, always contains hydrogen, which it gives off during the action of various bodies for which it has a powerful attraction. Thus, if equal weights of sulphur and copper or iron-filings be introduced into a retort, and heated, a quantity of hydrogen, mixed with sulphuretted hydrogen, is evolved at the period of their combination. B.

SECTION IV. *Phosphorus.*

Time of discovery.

578. PHOSPHORUS was discovered about the year 1669, by Brandt, an alchemist of Hamburgh, while employed in the research after the art of converting the baser metals into gold and silver; and afterwards by Kunckel, a German chemist. But the method of preparing it was not publicly divulged by either of these persons, and it was not till 1737 that a commission, appointed by the French Academy of Sciences, was instructed by a stranger in the process. It consisted in evaporating putrid urine to dryness, and distilling the residuum at an intense heat

in a stone-ware retort. Margraff improved the process by adding a salt of lead to the urine; and in 1769 Gahn, of Sweden, having discovered the phosphoric acid in bones, invented the method of preparing phosphorus which is now generally followed. H. 1. 358.

579. Phosphorus is obtained by distilling concrete phosphoric acid with half its weight of charcoal at a red heat. This mixture is put into the coated earthen retort, fig. 109 *a*, placed in a small portable furnace *b*; the tube of the retort should be immersed about half an inch into the basin of water *c*. A great quantity of gas escapes, some of which is spontaneously inflammable. and when the retort has obtained a bright red heat, a substance looking like wax, of a reddish colour passes over: this, which is impure phosphorus may be rendered pure by melting it under warm water, and squeezing it through a piece of fine shamois leather: but great care must be taken that none adheres to the nails or fingers, which would inflame on taking them out of the water, and produce a painful and troublesome burn. It is usually formed into sticks, by pouring it, when fluid, into a funnel tube under water. Method of preparing.

Phosphorus may also be procured by adding to urine a solution of lead in nitric acid, which precipitates a phosphate of lead. This, when well washed, dried, and distilled in a stoneware retort, yields phosphorus. Or a solution of phosphate of soda (which may be bought at the druggists), mixed with one of acetite of lead, in the proportion of one part of the former salt to 1¼ of the latter, yields a precipitate of phosphate of lead, from which phosphorus may be procured by distillation with charcoal, but at considerably more expense. H. 1. 369. Another process.

580. In performing this distillation, a high temperature is required, so that the furnace should be sufficiently capacious to hold a body of charcoal piled up above the retort, which as earthen ware becomes permeable to the vapour of phosphorus at a red heat, must be coated with a mixture of slaked lime and solution of borax; this mixture may be laid on with a brush, in two or three successive coats, and forms an excellent *vitrifiable lute.*

581. When pure, phosphorus is nearly colourless, semitransparent and flexible. Its specific gravity is 1,770. It melts, when air is excluded, at 105°. If suddenly cooled after having been heated to 140°, it becomes black: but if slowly cooled, remains colourless. At 550° it boils, air being excluded, and rapidly evaporates. When exposed to air, it exhales luminous fumes, having a peculiar alliaceous odour; it is tasteless and insoluble in water, but proves poisonous when taken into the stomach. (ORFILA, *Traité de Poisons*, II., P. ii., p. 186.) Properties.

If a cylinder of phosphorus be introduced into a vessel of oxygen gas, over mercury, at a temperature not exceeding 80° Fahrenheit, no perceptible absorption will happen in 24 hours; but if, the temperature remaining the same, the pressure be Exp.. Absorbs oxygen.

diminished to $\frac{1}{8}$th or $\frac{1}{10}$th that of the atmosphere, the phosphorus will be surrounded by white vapours, will become luminous in the dark, and will absorb oxygen. Under ordinary pressures, a higher temperature is required to produce this effect; but it is remarkable, that if the density of the oxygen be reduced in the above proportion, by mixing it with azote, hydrogen, or carbonic acid, the phosphorus becomes luminous. Hence phosphorus absorbs oxygen from atmospheric air with an extrication of light. H. 1. 359.

582. Phosphorus is inflamed by the application of a very gentle heat. According to Dr Higgins, a temperature of 60° is sufficient to set it on fire, when properly dry. It burns when heated to about 148°, (100° Brande) with a very brilliant light, or a white smoke, and a suffocating smell, and may even be inflamed in an atmosphere rarefied sixty times. (Van Marum.)

Exp. It may be set on fire by friction. Rub a very small bit between two pieces of brown paper; the phosphorus will inflame, and will set the paper on fire also.

Exp. In oxygen gas it burns with a very beautiful light; (262) and also in nitrous oxide, and chlorine gases. The product of the rapid combustion of phosphorus in oxygen gas is exclusively phosphoric acid. H. 1. 359.

In pure nitrogen, phosphorus is not the least luminous at any temperature.

Products of its imperfect combustion.

583. If, instead of burning phosphorus with free access of air, it is heated in a confined portion of very rare air, it enters into less perfect combustion, and three compounds of phosphorus with oxygen are the result, each characterized by distinct properties. The first is a red solid, less fusible than phosphorus; the second is a white substance, more volatile than phosphorus; and the third, a white and more fixed body.

Oxide.

584. The red solid consists of a mixture of phosphorus and oxide of phosphorus. *Oxide of phosphorus* is the white substance with which phosphorus becomes incrusted when kept for some time in water. It is very inflammable, and less fusible and volatile than phosphorus. It is this substance which is generally used in the *phosphoric match-boxes*. To prepare it for this purpose, a piece of phosphorus may be put into a small phial and melted and stirred about with a hot iron wire so as to coat its interior. A portion of the phosphorus is thus oxidized by its imperfect combustion, and a small quantity taken out upon the end of a brimstone match, instantly inflames upon coming into the contact of the air.

Solution in oil, &c.

585. Phosphorus is soluble in oils, and communicates to them the property of appearing luminous in the dark; alcohol and ether also dissolve it, but more sparingly. This may be shown

Exp. by pouring a small quantity of either of these liquids, in which phosphorus has been dissolved, upon the surface of warm water in a dark room.

Nature of phosphorus.

586. The only information, which we possess, respecting the nature of phosphorus, is derived from the electro-chemical researches of Sir H. Davy. When acted upon by a battery of 500 pairs of plates in the same manner as sulphur, gas was produced in considerable quantities, and the phosphorus became of a deep red-brown colour. The gas proved to be phosphuretted hydrogen, and was equal in bulk to about four times the phosphorus employed. Hence hydrogen may possibly be one of its components; but no confirmation of the truth of this view is derived from the recent experiments of the same philosopher, which, indeed, are rather contradictory to it. H. 1. 360.

587. *Phosphorus and Oxygen.*—Besides the oxide of phosphorus, which has just been alluded to, there are three *acid* compounds of phosphorus and oxygen, which have been termed *phosphorous*, *phosphoric*, and *hypophosphorus* acids.

Phosphorous acid.

588. *Phosphorous Acid.*—Phosphorous acid cannot, according to Sir H. Davy, be obtained pure by exposing cylinders of phosphorus to atmospheric air; for when thus prepared, it always contains phosphoric acid. It can only be obtained in a state of purity, first by subliming phosphorus through corrosive sublimate; then mixing the product with water and heating it, till it becomes of the consistence of syrup. Process. The liquid obtained is composed of pure phosphorous acid and water, which becomes solid and crystalline on cooling. It is acid to the taste, reddens vegetable blues, and unites with alkalies.

Theory.

589. The theory of this process is, that when the compound of phosphorus and chlorine, formed in the first operation, is brought into contact with water, the water is decomposed; its hydrogen uniting with chlorine composes muriatic acid; and its oxygen combining with phosphorus forms phosphoric acid. From this mixture of acids, heat expels the muriatic.

Properties.

590. The phosphorous acid exhales a disagreeable fetid odour; and yields, when strongly heated, penetrating white vapours. When heated in a glass ball, blown at the end of a small tube, a gas issues from the orifice of the tube, which inflames on coming into contact with the atmosphere. Hence it appears to contain an excess of phosphorus. Composition. The residuum in the ball is phosphoric acid. From the experiments of Rose on the phosphoric acid, Gay-Lussac infers that phosphorous acid must consist of

Phosphorus . .	56,81 . .	100 . .	132
Oxygen . . .	43,19 . .	76 . .	100
	100		

These proportions do not differ materially from those stated by Dulong, who makes phosphorous acid to consist of 100 phosphorus + 74,88 oxygen.* They agree, also, still more nearly, with the statement of Berzelius, according to whom this acid consists of

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* Phil. Mag. xlviii. 273.

Phosphorus	56,524	100,
Oxygen	43,476	76,92
	100	

Sir H. Davy, however, after a careful investigation of the constitution of phosphoric acid, has more lately been led to conclude that the oxygen, which it contains, is just one half of that existing in phosphoric acid; or that, in the former, 100 grains of phosphorus are united with only 67,5 of oxygen. Hence 100 grains of phosphorous acid must consist of

Phosphorus	59,7
Oxygen	40,3
	100.

And phosphorous acid, being probably constituted of 1 atom oxygen, + 1 atom of phosphorus, the weight of the latter atom may be inferred to be 11,62, or in round numbers 12. Phosphorous acid, then will be represented by 12 + 8 = 20. H. 1. 363.

Phosphoric acid. 591. *Phosphoric Acid* may be formed by burning phosphorus in excess of oxygen. There is intense heat and light produced, and white deliquescent flocculi line the interior of the receiver. It is produced in the same way by burning phosphorus under a dry bell-glass in atmospheric air. Phosphoric acid may also be obtained by acting upon phosphorus by nitric acid: in this case, if the action be at all intense, a portion of ammonia is at the same time produced, which is found in the state of phosphate of ammonia in solution. About six parts of nitric acid, specific gravity 1,4, are introduced into a tubulated retort placed in a sand heat, with a tubulated receiver luted on to it, the stopper of which should be open. When the acid is warm, drop into it gradually one part of phosphorus in small pieces; red nitrous vapour is instantly disengaged, and when evolution ceases, put the stopper loosely into the receiver, and distil till the residue in the retort acquires the consistence of syrup; pour it into a platinum crucible, and give it a dull red heat: it is pure phosphoric acid.

How obtained.

592. The exposure of *phosphate of ammonia* to a red heat in a platinum crucible, also affords very pure phosphoric acid.

A more economical method. 593. For the purpose of procuring phosphorus, phosphoric acid is most economically obtained by the decomposition of *bone earth,* which consists chiefly of phosphate of lime. The following is the mode of proceeding.

On 20 pounds of calcined bone, finely powdered, pour 20 quarts of water, and eight pounds of sulphuric acid, diluted with an equal weight of water. Let these materials be stirred together, and simmered for about 6 hours. Let the whole be then put into a conical bag of linen to separate the clear liquor, and wash the residuum till the water ceases to taste acid. Evaporate the strained liquor, and when reduced to about half its bulk, let it cool. A white sediment will form which must be allowed to subside; the clear solution must be decanted, and boiled to dryness in a glass vessel. A white mass will remain, which may be fused in a platinum crucible, and poured out into a clean copper dish. A transparent *glass* is obtained, consisting of phosphoric acid with some phosphate, and a little sulphate of lime.

Properties.

594. Phosphoric acid is a deliquescent substance, and when in the flocculent state, as obtained by burning phosphorus under a dry bell-glass, it dissolves in water with a hissing noise and excites great heat when a small particle is put upon the tongue; when fused it has been called *glacial phosphoric acid.* It is inodorous, very sour, volatile at a bright red heat, but unchanged by it. As commonly prepared, it is an unctuous fluid. Specific gravity = 2.

Composition.

595. The composition of these acids of phosphorus has been variously given by different chemists. Dulong investigated the composition of phosphoric acid, by finding how much chlorine is absorbed by phosphorus previously combined with a base. He then deduced the oxygen, from the quantity known to be the equivalent of the chlorine, which had disappeared. In this way he estimates the composition of phosphoric acid to be

Phosphorus . . .	44,48 . . .	100
Oxygen	55,52 . . .	124,8
	100,	

If 235 parts of phosphoric acid, as appears from the experiments of Sir H. Davy,[*] consist of 100 phosphorus, and 135 oxygen, 100 grains must contain

Phosphorus	42,55
Oxygen	57,45
	100,

This would very nearly accord with the notion, that phosphoric acid is constituted of one atom of phosphorus, weighing 12 and two atoms of oxygen = 16, and the weight of the atom of phosphoric acid will, therefore, be 28. It appears then, that we have three acids with base of phosphorus, which are constituted as follows:

	Atoms of Phosphorus.		Atoms of Oxygen.	Weight of atom.
Hypo-phosphorous acid .	2	+	1 . .	32
Phosphorous acid . . .	1	+	1 . .	20
Phosphoric acid . . .	1	+	3 . .	28

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[*] From late experiments Dr Thomson infers that 100 phosphorus combine with 133⅓ of oxygen to form phosphoric acid. (*First Principles.*)

Decomposition.

596. When distilled in an earthen retort with half its weight of powdered charcoal, glacial phosphoric acid is decomposed; its oxygen uniting with the carbon, forms carbonic acid, and phosphorus, in quantity equal to about ¼ of the acid, rises in a separate state. This is the usual and best mode of obtaining phosphorus H. 1. 368.

597. When phosphorus is exposed to a moist atmosphere, it undergoes an apparent deliquesence, producing a sour liquid composed of phosphorous and phosphoric acids and water. M. Dulong has called this *phosphatic acid.*

Hypopohsphorous acid.

598. *Hypophosphorous Acid* was discovered by M. Dulong, (*Annales de Chimie et Physique*, Vol. ii. p. 141.) It is prepared as follows: Upon 1 part of *phosphuret of barium* pour 4 parts of water, and when the evolution of phosphuretted hydrogen gas has ceased, pour the whole upon a filter. To the filtered liquid add sulphuric acid as long as any precipitate forms; separate the precipitate, which is a compound of sulphuric acid and baryta, and the clear liquor now contains the hypophosphorus acid in solution.

When concentrated by evaporation, a sour viscid liquid is obtained, incapable of crystallization, and eagerly attractive of oxygen.

599. The compounds of this new acid with alkaline and earthy bases, are remarkable for their extreme solubility. Those of barytes, and strontites crystallize with great difficulty. The *hypo-phosphites* of potash, soda, and ammonia, are soluble, in all proportions, in highly rectified alcohol. That of potash is even more deliquescent than muriate of lime. They absorb oxygen slowly from the air, and when heated in a retort give the same products as the acid itself.

In order to ascertain the properties of the elements of this acid, Dulong, its discoverer, converted a known quantity of it into phosphoric acid by means of chlorine, whence he infers it to consist of

Phosphorus . . .	72,75	100,
Oxygen	27,25	37,44
	100,	

These results are calculated on the supposition that the hypophosphorous or perphosphorous acid is a binary compound of oxygen and phosphorus; but it is doubtful whether it may not be a triple compound of oxygen, phosphorus, and hydrogen, or a *hydracid;* in which case its proper appellation would be *hydro-phosphorous acid.*

600. In his able investigation of the compounds of phosphorus, Sir H. Davy admits the existence of the new acid of Dulong, but deduces different proportions of its elements. The oxygen of this acid he infers to be the precise half of that which exists in phosphorous acid; or that 100 of phosphorus are united with

33,750 oxygen. But it has been already shown to be probable that phosphorous acid is composed of an atom of each of its elements, and it may, therefore, be inferred that hypo-phosphorous acid is constituted of one atom of oxygen weighing 8, and two atoms of phosphorus weighing $12\times2=24$, and the weight of the compound atom may be represented by 32. H. 1. 365.

601. *Phosphate of Ammonia* is a common ingredient in the urine of carnivorous animals. It may be obtained pure by saturating phosphoric acid with ammonia; it forms permanent octoëdral crystals soluble in two parts of water at 68°, and of a bitterish saline taste, specific gravity 1,8051. T.

It consists of . . . . 28 acid
17 ammonia
—
45

This salt is the best source of pure phosphoric acid, for if it be exposed to a red heat in a platinum vessel, the ammonia evaporates, and the acid is obtained in the form of a transparent glass, very deliquescent and pure. The phosphate of ammonia for this purpose may be conveniently and economically prepared by saturating the impure acid obtained from the bones (593) with carbonate of ammonia, filtering and evaporating to dryness.

Union with chlorine.

602. *Phosphorus and Chlorine.*—These elements unite in two proportions forming two definite compounds, the *chloride* and *perchloride* of phosphorus.

603. When phosphorus is submitted to the action of chlorine, it burns with a pale yellow flame, and produces a white volatile compound which attaches itself to the interior of the vessel, and which is the *perchloride of phosphorus.* This substance was long mistaken for phosphoric acid, but its easy volatility is alone sufficient distinction; it rises in vapour at 200°. It is fusible and crystallizable: and when brought into the contact of water, a mutual decomposition is effected, and phosphoric and muriatic acids result. When passed through a red-hot porcelain tube with oxygen, phosphoric acid is produced and chlorine evolved, which shows that oxygen has a stronger attraction for phosphorus than chlorine.

When phosphorus is burned in chlorine, one grain absorbs 8 cubic inches; so that the compound formed must be regarded as containing 1 proportional of phosphorus, and 2 of chlorine, or 12 of phosphorus + 72 of chlorine, and its number is 84.

604. With ammonia perchloride of phosphorus forms a singular compound, which though consisting of three volatile bodies, remains unchanged at a white heat, and is insoluble in water.

Chloride of phosphorus.

605. *Chloride of Phosphorus,* consisting of 12 phosphorus + 36 chlorine, is procured by distilling a mixture of phosphorus and *corrosive sublimate,* which is a perchloride of mercury. In this experiment *calomel,* or protochloride of mercury,

is formed, and the phosphorus combines with one proportional of chlorine.

Properties.

606. The chloride of phosphorus, when first obtained, is a liquid of a reddish colour: but it soon deposits a portion of phosphorus, and becomes limpid and colourless. Its specific gravity is 1,45. Exposed to the air it exhales acid fumes: it does not change the colour of dry vegetable blues. Chlorine converts it into perchloride. Ammonia separates phosphorus, and produces the singular triple compound as before adverted to (604.)

Acts upon water.

607. Chloride of phosphorus acts upon water with great energy, and produces muriatic and *phosphorous* acids, while the perchloride produces muriatic and *phosphoric* acids: for, as in the perchloride there are two proportionals of chlorine, so in acting upon water, two of oxygen must be evolved, which uniting to one of phosphorus generate phosphoric acid. The chloride of phosphorus on the contrary, containing one proportional of chlorine, produces muriatic acid and phosphorous acid, when it decomposes water, as the following tables show:

Before decomposition.

		Chloride of Phosp.			Water.
1 Chlorine	= 36	48.	1 Hydrog.	= 1	9.
1 Phospho.	= 12		1 Oxygen	= 8.	

After decomposition.

		Muriatic Acid.			Phosphorous Acid.
1 Chlorine	= 36	37	1 Phospho.	= 12	20
1 Hydrog.	= 1		1 Oxygen	= 8	

But the phosphorous acid, thus produced, always contains water, which it throws off when heated in ammonia, forming, with that alkali, a dry phosphite. This experiment shows that the *hydrophosphorous acid* consists of 2 proportionals of phosphorous acid = 40 + 1 water = 9, its number is therefore, 49.

Union with iodine.

608. *Phosphorus and Iodine.*—When these substances are brought together in an exhausted vessel, they act violently, and form a reddish compound; the *iodide of phosphorus* decomposes water with great energy, and produces phosphorous and hydriodic acids (390.) It consists of 12 phosphorous + 125, iodine = 137.

609. *Periodide of phosphorus* is a black compound, formed by heating one part of phosphorus with rather more than 20 of iodine. It consists according to Dr Thomson, of 1 proportional of phosphorus + 2 of iodine. It does not decompose water.

Union with hydrogen.

610. *Phosphorus and Hydrogen.—Phosphuretted Hydrogen.—Hydroguret of Phosphorus.*—When phosphorus is presented to nascent hydrogen, two gaseous compounds result. The one inflames spontaneously upon the contact of the atmosphere. This may be procured by heating phosphorus in a

solution of caustic potassa; or better, by acting upon *phosphuret of lime* by dilute muriatic acid.

Method of obtaining phosphuretted hydrogen.

611. In preparing this gas from phosphorus and solution of potash, for exhibiting its spontaneous accension, both the body and neck of the retort should be entirely filled with the solution, which Dr Coxe of Philadelphia recommends to be almost boiling hot. He employs a retort holding from half a pint to a pint; and after introducing both the phosphorus and the solution, fixes its neck on an inclined plane formed of a block of wood, fig. 110, the upper extremity of which is overhung by the body of the retort, while its mouth projects over the lower end, and is dipped into a small bowl filled with a hot solution of potash, as represented in the figure. The gas, extricated by the flame of a lamp, accumulates; and, forcing the alkaline solution down the neck, at length escapes, through the hot solution in the bowl, into the air, where it inflames. Should the heat slacken, and an absorption ensue, nothing passes into the retort but the hot solution of alkali from the bowl; and this, as the retort is secured from being displaced, does no harm. In this way a torrent of gas may be kept up, as long as there remains sufficient of the solution in the retort; and all danger of breaking the retort is avoided. H. 1. 427.

Thomson's method.

612. For obtaining this gas by the second process, Dr Thomson gives the following directions: Fill a small retort with water acidulated by muriatic acid, and then throw into it a quantity of phosphuret of lime in lumps. Plunge the beak of the retort under water, and place over it an inverted jar filled with that liquid. Phosphuretted hydrogen gas is extricated in considerable quantity, and soon fills the glass jar. Half an ounce of phosphuret of lime yields about 70 cubic inches of this gas.—Thomson's *System*, Vol. i. 272.

Properties.

613. This gas is colourless, has a nauseous odour like onions, a very bitter taste and inflames when mixed with air, a property which it loses by being kept over water; water takes up two *per cent.* of this gas, and acquires a bitter taste, and the smell of onions.

Exp.

614. When bubbles of phosphuretted hydrogen are sent up into a jar of oxygen, they burn with greatly increased splendour; in chlorine too they burn with a beautiful pale blue light, forming muriatic acid and perchloride of phosphorus. In a narrow tube it may be mixed with oxygen without exploding, in which case it is deprived of its phosphorus without suffering any change of bulk. It burns when thrown up into nitrous oxide.

Composition.

615. For our knowledge of the composition of this gas, we are chiefly indebted to Dr Thomson, who has shown that the hydrogen suffers no change of bulk in uniting to the phosphorus; so that the difference of weight between this gas and pure hydrogen, indicates the weight of phosphorus; 100 cubic inches of phosphuretted hydrogen weigh 27,527 grains; hence

the gas may be regarded as containing one proportional of phosphorus and one of hydrogen, or $12 + 1 = 13$. Its specific gravity is very variable. Sir H. Davy has obtained it, from phosphorus and alkaline lixivia, of all specific gravities, from ,400 to ,700; Mr Dalton states it at ,850, air being 1,000, and Dr Thomson at ,902,2. The quantity absorbed by water is fixed by the former at $\frac{1}{40}$ to its bulk, and by the latter at $\frac{1}{27}$. Dr Thomson makes it $\frac{1}{50}$. H. 1. 428.

616. When phosphuretted hydrogen is mixed with oxygen, it requires a volume and a half of the latter gas for its perfect combustion; and as the hydrogen would require half its volume of oxygen for the production of water, the remaining volume must unite to the phosphorus to produce phosphoric acid.

Hydrophosphoric gas.

617. *Bihydroguret of phosphorus.—Hydrophosphoric Gas.*—The next compound of phosphorus and hydrogen has been called, by Sir H. Davy *hydrophosphoric gas.* It is procured by heating the solid hydrophosphorous acid in a very small retort. The gas must be collected over mercury, for water absorbs one-eighth its volume. Its specific gravity to hydrogen is as 14 to 1, 100 cubical inches weigh 29,645 grains. It is not spontaneously inflammable, but explodes when heated with oxygen. It inflames spontaneously in chlorine, one volume requiring four of chlorine for its perfect combustion. Its smell is less disagreeable than the former. It consists of 2 of hydrogen and 1 of phosphorus $\overset{H}{2} + \overset{P}{12} = 14$; but the two volumes of hydrogen are condensed into one; consequently when the gas is decomposed, as for instance, by subliming sulphur in it, two volumes of sulphuretted hydrogen are formed.

618. There is not, says Sir H. Davy, in the whole series of chemical phenomena a more beautiful illustration of the theory of definite proportions, than that offered in the decomposition of hydrophosphorous acid into phosphoric acid, and hydrophosphoric gas. Four proportions of the acid contain four proportions of phosphorus, and four of oxygen; two proportions of water contain four proportions of hydrogen and two of oxygen (all by volume). The six proportions of oxygen unite to three proportions of phosphorus to form three of phosphoric acid, and the four proportions of hydrogen combine with one of phosphorus to form one proportion of hydrophosphoric gas; and there are no other products. *Elements* p. 297.

619. *Phosphorus and Nitrogen* produce no definite compound, though in some cases of animal decomposition the evolved nitrogen appears to hold phosphorus in solution.

Union with sulphur.

620. *Phosphorus and Sulphur* are capable of combining. They may be united by melting them together in a tube exhausted of air, or under water. In this last case they must be used in small quantities; at the moment of their action, water is decomposed, sometimes with explosions. They unite in many proportions. The most fusible compound is that of one

and a half of sulphur to two of phosphorus. This remains liquid at 40° F. When solid, its colour is yellowish-white. It is more combustible than phosphorus, and distils undecomposed at a strong heat. U. 638. (See, also, FRADAY *Jour. Roy. Institut.* iv. 361.)

SECTION V. *Carbon.*

Diamond.

621. The purest form of this elementary substance is the diamond, a mineral body first discovered in Asia. Diamonds occur in Brazil in crystals in secondary rocks, as several kinds of sandstone, consisting of aggregated quartz pebbles. Also in strata of ferruginous sand and clay; and in the loose sand of plains and rivers.* The fracture of the diamond is foliated, its laminæ being parallel to the sides of a regular octoëdron. It is brittle and very hard. Specific gravity 3,5. The weight and value of diamonds is estimated in *carats*, 150 of which are about equal to one ounce troy, or 480 grains.†

622. The diamond, which Sir I. Newton had sagaciously inferred to be a combustible body, from its powers of refracting light, was first shown by Guyton‡ to contain carbon, and his experiments led him to conclude that the diamond is the only form of pure carbon; and that charcoal is a compound of carbon and oxygen, or an oxide of carbon. The experiments of Messrs. Allen and Pepys have, however, gone far towards proving that the diamond and charcoal, though so widely remote from each other in external characters, are, as to their chemical nature, identically the same; and that the difference between them, in all probability, results merely from the respective states of aggregation of their particles. H. 1. 328.

Charcoal.

623. Another form of carbon is *charcoal*, the purest variety of which is *lamp-black*.

Charcoal may be prepared by heating pieces of wood, covered with sand, to redness, and keeping them in that state for about an hour. They are converted into a black brittle substance, which appears to be the same from whatever kind of wood it has been procured.

Method of preparing charcoal

Common charcoal employed as fuel is usually made of oak, chesnut, elm, beech, or ash wood, the white and resinous woods being seldom used. Young wood affords a better charcoal than large timber, which is also too valuable to be thus employed. It is formed into a conical pile, which being covered with earth, or clay, is suffered to burn with a limited access of atmospheric air, by which its complete combustion, or reduction to ashes, is prevented.

Another, and a more perfect mode of preparing charcoal, consists in submitting it to a red heat in a kind of distillatory apparatus consisting of cast iron cylinders, from which issue one or more tubes for the escape of gaseous matters. The makers of gunpowder particularly prefer this process. (A plate of this apparatus is given by Mr Parkes, in his *Chemical Essays.*)

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* Moh's Mineralogy, ii. 300.

† Jameson's Mineralogy, i.

‡ Ann. de Chimie, xxxi.

Lamp-black.

624. Lamp-black is prepared principally by turpentine manufacturers from refuse and residuary resin, which is burned in a furnace, so constructed, that the dense smoke arising from it may pass into chambers hung with sacking, where the soot is deposited, and from time to time swept off, and sold without any further preparation. (AIKIN's *Dictionary.* Art. CHARCOAL.) When lamp-black has been heated red hot in a close vessel, it may be considered as very pure carbon.

625. The quantity of charcoal obtained from different kinds of wood is liable to much variation. From 100 parts of the following woods, Messrs. Allen and Pepys obtained the annexed quantities of charcoal.—*Phil. Trans.* 1807.

Beech	15,00	Oak	17,40
Mahogany	15,75	Fir	18,17
Lignum Vitæ . . .	17,25	Box	20,25

626. Charcoal is a black, insoluble, inodorous, insipid, brittle substance; an excellent conductor of electricity, but a bad conductor of heat; unchanged by the combined action of air and moisture at common temperatures; and easily combustible in oxygen gas.

Its properties.

Fusion of Charcoal.

627. Professor Silliman first observed, on subjecting cylindrical pieces of charcoal, tapered to a point, to the galvanic *deflagrator* of Dr Hare, (237) when in powerful action, that the charcoal point of the positive pole instantly shot out $\frac{1}{16}$th, $\frac{1}{8}$th, or even $\frac{1}{4}$ of an inch. The charcoal of the negative pole underwent, in the mean time a change precisely the reverse, its point disappearing, and a crater-shaped cavity being substituted in its stead. By placing a piece of metal at the negative pole in lieu of charcoal; it was ascertained by the absence of the usual phenomena, that the increase, before observed in the charcoal at the positive pole, was occasioned by an actual transference of charcoal, from the former to the latter. On examining with a magnifier the projecting point of the charcoal at the positive pole, it was found to have undergone distinct fusion into small spheres collected into botryoidal or mamillary concretions. The charcoal after being thus fused, is found to have become much harder, and to have acquired a great increase of specific gravity, sinking readily to the bottom of strong sulphuric acid. Its combustibility is so much diminished, that it remains unaltered, when ignited on an iron plate with free access of air; but in a close vessel of oxygen gas, it was found entirely convertible into carbonic acid by the solar rays concentrated upon it by a powerful lens. (*American Journal of Science,* v. 108 —361.)

628. Charcoal is capable of destroying the smell and taste of a variety of vegetable and animal substances. (LOWITZ *Crell's*

of its oxygen. Upon this principle, carbonic oxide gas is produced by heating in an iron retort a mixture of chalk and charcoal; or of equal weights of chalk and iron or zinc filings. It is also obtained by the distillation of the white oxide of zinc with one-eighth of its weight of charcoal, in an earthen or glass retort; from the scales which fly from iron in forging, mixed with a similar proportion of charcoal; from the oxides of lead, manganese, or, indeed, of almost every imperfect metal, when heated in contact with powdered charcoal. It may also be obtained from the substance which remains after preparing acetic acid from acetate of copper. But the mixture that affords it most pure, is equal parts of carbonate of baryta and clean iron filings; these should be introduced into a small earthen retort, so as nearly to fill it, and exposed to a red heat: the first portion of gas being rejected as mixed with the air of the retort, it may afterwards be collected quite pure.

How obtained.

It may also be obtained by transmitting carbonic acid gas over charcoal ignited in a porcelain tube. The acid gas combines with an additional dose of charcoal; loses its acid properties; and is converted into the carbonous oxide. An ingenious apparatus, contrived by M. Baruel, and extremely useful for this and similar purposes is represented by fig. 111. A is the bottle from which the carbonic acid gas is extricated; C, a tube nearly filled with pieces of muriate of lime to attract moisture; F, a reverberatory furnace in which three gun barrels x x' x'' are placed, containing the charcoal, and communicating with each other by glass tubes d d; m, the tube that conveys the carbonic acid gas into the first gun barrel x; lastly, t t, the bent tube by which the carbonic oxide produced, passes. The last product of the distillation is the purest, but still contains carbonic acid, which must be separated by washing the gas with lime liquor.

634. The nature of this gas was first made known by Mr Cruickshanks, of Woolwich, in 1802 (NICHOLSON's 4to *Journal*, v.); and about the same time it was examined by Messrs. Clement and Desormes. *Annales de Chimie*, xxxix.

635. Its specific gravity to hydrogen is as 14 to 1; 100 cubical inches weighing 29,63 grains[*]. It extinguishes flame, and burns with a pale blue lambent light, when mixed with, or exposed to atmospheric air. The temperature of an iron wire heated to dull redness was found by Sir H. Davy sufficient to kindle it. A mixture of two measures with one of common air may, be exploded by a lighted taper, or even by red-hot iron or charcoal. H. 347.

Properties.

636. It is extremely noxious to animals; and fatal to them if confined in it. When respired for a few minutes, it produces giddiness and fainting.[†]

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[*] 29,6527. Its specific gravity air = 1 is 0,9722
oxygen = 1 0,875. T.

[†] See Phil. Mag. xl. iii 367.

637. When a stream of carbonic oxide is burnt under a dry ell-glass of air or oxygen, no moisture whatever is deposited, howing, that it contains no hydrogen.

Detonates with oxygen.

638. When two volumes of carbonic oxide, and one of oxy-en, are acted on by the electric spark, a detonation ensues, and wo volumes of carbonic acid are produced. Whence it appears, hat carbonic acid contains just twice as much oxygen as car-onic oxide, which may be considered as a compound of one olume of oxygen and one volume of gaseous carbon; or of one roportional of carbon and one of oxygen, the latter being so xpanded as to occupy two volumes.

639. Carbonic oxide suffers no change by being passed and epassed through a red-hot porcelain tube; nor is it decomposed t high temperatures by phosphorus, sulphur, nor even, accord-ng to the experiments of Saussure, by hydrogen. (*Journal le Physique*, lv.) But when previously mingled with an equal ulk of hydrogen gas, and passed through an ignited tube, the ube becomes lined with charcoal. In this temperature, the ydrogen attracts oxygen more strongly than it is retained by he charcoal, and water is formed. It was found, also, by Gay-ussac, to be decomposed by the action of potassium, which ombines with the oxygen and precipitates charcoal. H. 1. 47.

Decomposed by potassium and sodium.

640. None of the metals exert any action upon this gas, ex-ept potassium and sodium, which at a red heat, burn in it by bstracting its oxygen, and carbon is deposited.

Composition.

641. According to Mr Cruickshank, it contains per cent. about 0 oxygen, and 30 carbon by weight: or the former is to the tter as 21 to 8,6, or as 21 to 9. Gay-Lussac however, makes t to consist of 43 charcoal and 57 oxygen; Berzelius of 44,28 harcoal and 55,72 oxygen, proportions which agree within a mall fraction with those of Clement and Desormes. It con-ains, therefore, just half the oxygen that exists in carbonic acid, nd it is constituted of one atom of charcoal and one atom of xygen, and weighs, according to Mr Dalton, $7 + 5,4 = 12,4$, r, by the corrected numbers $8 + 6 = 14$.

On the theory of volumes it consists of 1 vol. of oxygen + 1 ol. of gaseous carbon, the oxygen being in such a state of xpansion as to occupy the space of two volumes. H. 1. 348.

Chloro-carbonic acid.

642. *Chloro-carbonic Acid—Phosgene gas.*—When equal olumes of chlorine and carbonic oxide gases, both previously ried by fused chloride of calcium, are introduced into a flask hich has been exhausted of air, and are then exposed to bright unshine for a quarter of an hour, combination takes place, the olour of the chlorine disappears, and the constituent gases are ondensed into half their united volumes. Hence its specific ravity must be equal to the specific gravity of chlorine 2,5 + hat of carbonic oxide $0,9722 = 3,4722$, and 100 cubic inches ust weigh 105,9 grains.* Being produced by the agency of

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* 105,9020. Sp. gr. 3,125 oxygen = 1. T.

light, it was called by Dr J. Davy *phosgene gas*, but as it exhibits distinctly acid properties, it has since been better termed *chloro-carbonic acid*. It is constituted of an atom of carbon, an atom of oxygen, and an atom of chlorine. Its equivalent, therefore, is $14 + 36 = 50$. H. 2. 665.

Properties.

It has a peculiar pungent odour and excites a copious flow of tears. It is soluble in water, and is resolved into carbonic and muriatic acid gases. The weight of chloro-carbonic acid to hydrogen is as 50 to 1. It condenses four times its volume of ammoniacal gas, producing a white neutral salt from which the more powerful acids disengage muriatic and carbonic acids, but acetic acid dissolves it without effervescence. Several of the metals decompose it, and unite with the chlorine, evolving carbonic oxide equivalent in volume to the original gas.

Chloro-carbonic gas affords then an example of an acid with a simple base, and two acidifying principles, oxygen and chlorine, which are not often united in the performance of this function. H. 2. 665.

643. *Carbonic Acid Gas* may be obtained by burning carbon, either pure charcoal or the diamond, in oxygen gas.

Combustion of the diamond.

644. It is not evident to whom the combustibility of the diamond first occurred; but in the year 1694 the Florentine Academicians proved its destructibility by heat by means of a burning lens. The *products* of its combustion were first examined by Lavoisier in 1772, and subsequently with more precision by Guyton Morveau, in 1785. (*Annales de Chimie*, xxxi.) In 1797, Mr Tennant demonstrated the important fact, that when equal weights of diamond and pure charcoal were submitted to the action of red hot nitre, the results were in both cases the same; and in 1807 the combustion of the diamond in pure oxygen was found by Messrs Allen and Pepys to be attended with precisely the same results as the combustion of pure charcoal. Hence the inevitable inference that charcoal and the diamond are similar substances in their chemical nature, differing only in mechanical texture.*

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* The apparatus fig. 110 may be conveniently employed for exhibiting the results of the combustion of the diamond. It consists of a glass globe, of the capacity of about 140 cubical inches, furnished with a cap, having a large aperture; the stop-cock, which screws into this cap, has a jet, *a*, rising from it, nearly into the centre of the globe; this is destined to convey a small stream of hydrogen, or other inflammable gas. Two wires, *c c*, terminate at a very little distance from each other, just above this jet, and are intended to inflame the stream of hydrogen by electrical sparks; one of them commences from the side of the jet, the other is enclosed and insulated nearly in its whole length in a glass tube: the tube and wire pass through the upper part of the stop-cock, and the wire terminates on the outside in a ball or ring, *d*, at which sparks are to be taken from the machine, either directly or by a chain. On the end of the jet is fixed, by a little socket, a small capsule, *b*, made of platinum foil. This capsule is pierced full of small holes, and serves as a grate to hold the diamonds. Its distance is about three-quarters of an inch from the end of the jet; and the arm, by which it is supported, is bent round, so that the stream of hydrogen shall not play against it. The stop-cock screws, by its lower termination, on to a small pillar, fixed on a stand, and at the side of this pillar is an aperture by which a bladder filled with gas may be connected with the apparatus.

On using the apparatus, the diamond is to be placed in the capsule; and then the globe being screwed on to the stop-cock, the latter is to be removed from the pillar and placed on the air-pump; the globe is then to be exhausted, and afterwards filled with pure oxygen: or, lest the stream of oxygen

Allen and Pepys's apparatus.

645. Messrs Allen and Pepys collected the product of the combustion of charcoal and of the diamond, by means of the apparatus represented by fig. 111. (*Phil. Trans.* 1807.) *a a* are mercurial gasometers, one of which is filled with pure oxygen gas. The brass tubes *b b*, properly supplied with stopcocks, issue from the gasometers, and are connected with the platinum tube *c c*, which passes through the small furnace *d*. *e* is a glass tube passing into the mercurio-pneumatic apparatus by which the gas may be drawn out of the gasometers into convenient receivers. A given weight of diamond is introduced into the centre of the platinum tube, which is then heated to bright redness, and the gas passed over it, backwards and forwards, by alternately compressing the gasometers. Carbonic acid is soon formed, and it will be found that the increase of weight sustained by the oxygen is equivalent to that lost by the diamond; that the oxygen undergoes no change of bulk; and that the results are, in all respects, similar to those obtained by a similar combustion of perfectly pure charcoal.

Results.

646. From the quantity of charcoal or diamond consumed in the experiments of Allen and Pepys, and the quantity of oxygen converted into carbonic acid, it is easy to infer the proportion of carbon and oxygen in the new compound. Reducing these to centesimal proportion, for every 28 or 29 grains of the combustible base which disappeared, 100 grains of carbonic acid (= about 201 cubic inches) were generated; and it is remarkable that these proportions agree exactly with those originally stated by Lavoisier. The same quantity of carbonic acid resulted, also, from the combustion of between 28 and 29 grains of diamond. Hence it may be inferred, that the actual quantity of carbon in equal weights of diamond and charcoal is very nearly the same; and that charcoal is not, as has hitherto been supposed, an oxide of carbon; their only difference consisting in the presence of hydrogen in charcoal, in so small proportion as not materially to diminish the quantity of carbonic acid produced by its combustion. If this inference required confirmation, it is furnished by its agreement with Mr Tennant's experiments on the combustion of the diamond, published in 1797. Two grains and a half of diamond, (this philosopher found), when consumed in a tube of gold by means of nitre, give nine grains of carbonic acid, which, in 100 parts, should contain, therefore, as nearly as possible, 28 parts of diamond or carbon. The mean

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in entering should blow away the diamond, the globe may be filled with the gas first, and then, dexterously taking out the stop-cock for a short time, the diamonds may be introduced and the stop-cock replaced. The apparatus is then to be fixed on the pillar, and a bladder of hydrogen gas attached to the aperture. Now, passing a current of sparks between the wires, a small stream of hydrogen is to be thrown in, which inflaming, immediately heats the capsule and diamonds white hot; the diamonds will then enter into combustion, and the hydrogen may be immediately turned off and the bladder detached. The diamonds will continue to burn, producing a strong white heat, until so far reduced in size as to be cooled too low by the platinum with which they lie in contact.

of a number of Messrs Allen and Pepys experiments give the following statement of the composition of carbonic acid:

Carbon	28,60	100
Oxygen	71,40	250
	100.	

Composition of Carbonic acid.

647. Mr Dalton assumes the composition of carbonic acid to be in round numbers, 28 of charcoal and 72 of oxygen; from whence he deduces the weight of the atom of charcoal to be 5,4. But if the atom of oxygen weigh 8, and if the proportions just assigned be correct, the atom of charcoal will weigh 6, and that of carbonic acid (considering it as a ternary compound of two atoms of oxygen and one of charcoal) will be 16 + 6 = 22. On the theory of volumes its constitution has been stated by Gay-Lussac to be 1 volume of gaseous carbon + 1 volume of oxygen, condensed into the space of 1 volume, and the density of the vapour of charcoal has been estimated to be equal to the density of carbonic acid, less that of oxygen gas, or to 1,5245 —1,1025 = 0,422.*

648. When two volumes of carbonic oxide are converted into carbonic acid, we add a volume of oxygen equal to that already existing in two measures of the former gas *viz.* one volume, and obtain two volumes of carbonic acid, which gas may therefore be considered, under this aspect, as constituted of one volume of oxygen + half a volume of carbonic oxide condensed into one volume. This view of the constitution of carbonic acid and carbonic oxide rests, however, it is evident, upon the presumption that the general law, deduced by the last mentioned philosopher from a variety of other cases, applies in this instance; viz. that *gaseous compounds either contain equal volumes of their elements, or that if either exceed, the excess is by some simple multiple of the smaller volume.*†

Proofs from analysis.

649. In addition to the proofs of the constitution of carbonic acid derived from its synthesis, we have also the evidence of its analysis, which may be effected by several processes.

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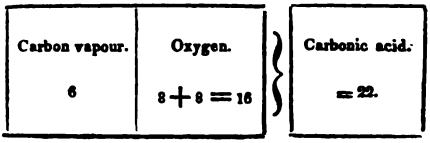
* Sp. gr. of Carbon vapour . . . . 0,375 } Oxygen = 1.
" " " Carbonic acid . . . . 1,375 }
Atomic weight of ditto . . . . . 2,75 }
Weight of 100 cubic inches . . . . 46,5972. T.

† According to Professor Brande 100 cubic inches of oxygen weigh 33,88 grains; 100 cubic inches of carbonic acid weigh 46,57 grains, or just 22 times as heavy as hydrogen, hence 100 cubical inches of carbonic acid must consist of 33,88 grains of oxygen + 2,70 grains of carbon, and 12,7 : 33,88 : : 8 : 10. Hence 1 proportional of charcoal = 6 + 2 proportionals of oxygen = 16 will constitute carbonic acid, represented by the number 22, or by the following symbol.



1. By passing a succession of electrical discharges through a quantity of carbonic acid gas confined over mercury, Dr Henry has found that the gas is separated into oxygen, and carbonic oxide. When the carbonic acid, which escapes decomposition, has been washed out by a solution of potash, an electric spark inflames the residuary mixture; the oxygen and carbonic oxide again uniting, and re-composing carbonic acid.*

2. When a mixture of carbonic acid and hydrogen gases is electrified, the hydrogen combines with part of the oxygen of the acid, and reduces it to the state of carbonic acid. The same products are obtained, by transmitting a mixture of two parts of hydrogen gas and one of carbonic acid through a glazed porcelain tube strongly ignited. The hydrogen, uniting with a part of the carbonic acid, brings the latter to the state of carbonic oxide, at the same time that water is formed. H. 1. 338.

650. It may also be analyzed by the action of the metal *potassium*, which is capable of abstracting its oxygen, and, with the aid of heat, burns in it with great splendour; charcoal is deposited, and an *oxide of potassium* is formed. In this and in some other cases, oxygen is seen alternately producing acid and alkali. If carbonic acid, obtained by burning the diamond in oxygen, be thus decomposed by potassium, the carbon makes its appearance in the form of charcoal, equal in weight to the diamond consumed.

651. Carbonic acid is a most abundant natural product; the best mode of procuring it for experiment consists in acting upon marble (*carbonate of lime*) by dilute muriatic acid.

Method of obtaining carbonic acid.

For this purpose the marble, in small fragments, is introduced into the two-necked bottle *a*, fig. 112, and covered with water; muriatic acid is then slowly poured down the funnel *b*, which causes an immediate effervescence, and the gas passes through the bent tube *c*, into the inverted jar *d*. When the action ceases, it may be renewed by the addition of fresh acid, until the whole of the marble is dissolved.

As carbonic acid gas is heavier than atmospheric air it may also be obtained by means of the apparatus fig. 113, *a* is a long glass tube proceeding from the bottle containing the marble and acid, and passing down to the bottom of the jar *b*, which stands with its mouth uppermost. The carbonic acid will expel the common air from the jar.

652. Carbonic acid may be collected over water, but must be preserved in vessels with glass-stoppers, since water, at common temperature and pressure, takes up its own volume.

Exp.

Fill partly a jar with this gas, and let it stand a few hours over water. An absorption will gradually go on, till at last none will remain. This absorption is infinitely quicker when agitation is used. Repeat the above experiment, with this difference, that the jar must be shaken strongly. A very rapid diminution will now take place. In this manner, water may be charged with rather more than its own bulk of carbonic acid gas; and it acquires, when thus saturated, a very brisk and pleasant taste.

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* Phil. Trans. 1809, 448.

Absorbed by water.

653. The effervescent quality of many mineral waters is referable to the presence of this gas, and they are often imitated by condensing carbonic acid into water, either by a condensing pump, of which a description is given in Mr Pepys (*Quarterly Journal of Science and the Arts*, Vol. iv. p. 305) or by a Nooth's apparatus, as represented in fig. 114. It consists of three vessels, the lowest, *a*, flat and broad, so as to form a steady support; it contains the materials for evolving the gas, such as pieces of marble and dilute muriatic acid, of which fresh supplies may occasionally be introduced through the stopped aperture. The gas passes through the tube *b*, in which is a glass valve opening upwards, into the vessel *c*, containing the water or solution intended to be saturated with the gas, and which may occasionally be drawn off by the glass stop-cock. Into this dips the tube of the uppermost vessel *d*, which occasions some pressure on the gas in *c*, and also produces a circulation and agitation of the water. At the top of *d* is a heavy conical stopper, which acts as an occasional valve, and keeps up a degree of pressure in the vessels.

Under a pressure of two atmospheres water dissolves twice its volume of this gas, and so on. It thus becomes brisk and tart, and reddens delicate vegetable blues. By freezing, boiling or exposure to the vacuum of the air-pump, the gas is given off.

Exp.

Place a tumbler of water which has been impregnated with this gas (the soda water of the shops, for example) under the receiver of the air-pump, and exhaust it; the gas will escape so rapidly as to present the appearance of ebullition; and will be much more remarkable than the discharge of air from another vessel of common spring water, confined at the same time under the receiver.

Expelled by freezing.

Exp.

654. If the impregnated water be rapidly congealed, by surrounding it with a mixture of snow and salt, the frozen water has more the appearance of snow than of ice, its bulk being prodigiously increased by the immense number of air bubbles. When water, thus congealed, is liquefied again, it is found, by its taste, and other properties, to have lost nearly the whole of its carbonic acid.

Fatal to animals.

Exp.

655. Carbonic acid gas is unrespirable, and is fatal to animals. Put a mouse or other small animal into a vessel of the gas, and cover the vessel to prevent the contact of common air. The animal will die in the course of a minute or two. By means of this gas, butterflies, and other insects, the colours of which it is desirable to preserve, for the purpose of cabinet specimens, may be suffocated better than by the conmon mode of killing them by the fumes of sulphur. H.

Does not support combustion.

656. It extinguishes flame. This may be shown by setting a vessel filled with the gas, with its mouth upwards, and letting

down a lighted candle. The candle will be instantly extinguished.

Exp.

The experiment may be varied by placing near the vessel containing the carbonic acid gas, a similar one filled with oxygen gas, and if the candle after being extinguished by the carbonic acid be speedily immersed in the oxygen gas it will be re-lighted, and this may be repeated as long as the gases remain in the vessels.

Heavier than atmospheric air.

657. Carbonic acid gas is heavier than atmospheric air, and may be poured from one vessel into another like water. Place a lighted taper at the bottom of a tall glass jar, and pour the gas out of a bottle into it ; it descends and extinguishes the flame, and will remain a long time in the lower part of the jar. Hence in wells and in some caverns, carbonic acid gas frequently occupies the lower parts, while the upper parts are free from it. Hence also the precaution used by the sinkers of wells, of letting down a candle before they venture to descend in person. The miners call it *choak damp*.

Exp.

Possesses acid properties.

658. When combined with water this gas reddens vegetable colours. This may be shown by dipping into water, thus impregnated, a bit of litmus paper, or by mixing, with a portion of it about an equal bulk of the infusion of litmus. This fact establishes the title of the gas to be ranked among acids. When an infusion of litmus which has been thus reddened, is either heated, or exposed to the air, its blue colour is restored, in consequence of the escape of the carbonic acid. This is a marked ground of distinction from most other acids, the effect of which is permanent, even after boiling.

Exp.

Test of its presence.

Carbonic acid gas precipitates lime-water—this character of the gas is necessary to be known, because it affords a ready test of the presence of carbonic acid, whenever it is suspected. Pass the gas as it proceeds from the materials, through a portion of lime water. This, though perfectly transparent before, will instantly grow milky : Or, mix equal measures of water saturated with carbonic acid, and lime water. The same precipitation will ensue. By means of lime-water, the whole of any quantity of carbonic acid, existing in a mixture of gases, cannot, however be removed, as Saussure, jun. has shown ; but recourse must be had in order to effect an entire absorption, to a solution of caustic potash or soda.*

Exp.

A product of combustion.

As all common combustibles, such as coal, wood, oil, wax, tallow, &c. contain carbon as one of their component parts, so the combustion of these bodies is always attended by the production of carbonic acid. 1. Let the chimney of a portable furnace, in which charcoal is burning, terminate, at a distance sufficiently remote to allow of its being kept cool, in the bottom of a barrel, provided with a moveable top, or of a large glass vessel, having two openings. A small jar of lime-water being

Exp.

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* If excess, either of the gas or of its aqueous solution, be added to the lime water, the precipitate is re-dissolved, carbonate of lime being soluble in carbonic acid.

et down into the tub or vessel, and agitated, the lime-water will immediately become milky. The gas will also extinguish burning bodies, and prove fatal to animals that are confined in it. Hence the danger of exposure to the fumes of charcoal, which, in several instances have been known to be fatal. These fumes consist of a mixture of carbonic acid and nitrogen gases with a very small proportion of oxygen gas. 2. Fill the pneumato-chemical trough with lime-water, and burn a candle, in a jar filled with atmospheric air, over the lime water till the flame is extinguished. On agitating the jar, the lime water will become milky. The same appearances will take place, more speedily and remarkably if oxygen gas be substituted for common air. The carbonic acid, thus formed during combustion, by its admixture with the residuary air, renders it more unfit for supporting flame, than it otherwise would be from the mere loss of oxygen. Hence, if a candle be burnt in oxygen it is extinguished long before the oxygen is totally absorbed; because the admixture of carbonic acid with oxygen gas, in considerable proportion, unfits it for supporting combustion. Whenever any substance, by combustion in oxygen gas or common air over lime water, gives a precipitate, soluble with effervescence in muriatic acid, we may infer that it contains carbon. H. 1. 343.

Exp.

And of respiration.

659. It is also produced by the respiration of animals; hence it is detected often in considerable proportion, in crowded and illuminated rooms, which are ill ventilated, and occasions difficulty of breathing, giddiness, and faintness.

Exp.

The production of carbonic acid, by respiration, may be proved by blowing the air from the lungs, with the aid of a quill, through lime water, which will become milky.

660. In the atmosphere it may also be detected, varying in quantity from 1 to 0,1 *per cent.*

Retards putrefaction.

661. Carbonic acid retards the putrefaction of animal substances. This may be proved, by suspending two equal pieces of flesh meat, the one in common air, the other in carbonic acid gas, or in a small vessel through which a stream of carbonic acid is constantly passing. The latter will be preserved untainted some time after the other has begun to putrefy.

Its effect on vegetables.

Carbonic acid gas exerts powerful effects on living vegetables. These effects, however, vary according to the mode of its application. Water saturated with this gas, proves highly nutritive, when applied to the roots of plants. The carbonic acid is decomposed, its carbon forming a component part of the vegetable, and its oxygen being liberated in a gaseous form.

On the contrary, carbonic acid, when a living vegetable is confined in the undiluted gas over water, is injurious to the health of the plant, especially in the shade. The late Mr Henry long ago found, that a certain quantity of this gas, applied as an atmosphere, is favourable to vegetation; and M. Saussure of Geneva, has determined more recently, that the mixture of more than $\frac{1}{8}$ of carbonic acid with common air is always injurious; but that, in this proportion, it produces the growth of plants, and is manifestly decomposed.

662. It is this process of nature that appears to be the principal means of preventing an excess of carbonic acid in the general mass of the atmosphere, which, without some provision of this kind, must gradually, in the course of ages, be rendered less and less fit for respiration. H. 1. 345.

Carbonates.

663. Carbonic acid combines with alkalies. earths and metals and the compounds are termed *carbonates:* as it is usually retained in combination by very feeble affinity, so it is evolved from most of the carbonates by the simple operation of heat. Thus chalk, when heated. gives out carbonic acid and becomes *quicklime.* It is also evolved from its combinations by most of the other acids; and if nitric, muriatic, or sulphuric acid, be poured upon the carbonates, the presence of carbonic acid is indicated by *effervescence.*

Decomposition.

664. If carbonic acid be passed over red-hot charcoal, it becomes converted into carbonic oxide by taking up an additional proportion of base. The blue flame, often seen upon the surface of a charcoal fire, arises from the combustion of the carbonic oxide formed in this way; the air entering at the bottom, forms carbonic acid, which, passing through the red-hot charcoal, becomes converted into carbonic oxide.

665. At a bright red heat, iron decomposes carbonic acid, by abstracting a portion of its oxygen, and forming oxide of iron and carbonic oxide.

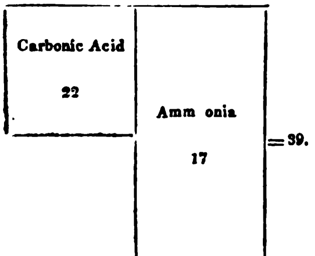
Carbonate of Ammonia.

666. *Carbonic Acid and Ammonia.*—These gases readily combine, and produce one of the most useful and best known of the ammoniacal compounds. When one volume of carbonic acid gas and two volumes of ammonia are mixed in a glass vessel, over mercury, a complete condensation ensues, and *carbonate of ammonia* is produced.

As 100 cubic inches of carbonic acid weigh 46,56 grains. and 200 of ammonia 36,36 grains, in all 82,92 grains, carbonate of ammonia must consist of

		Atoms.	
Carbonic acid	56,20	1	22
Ammonia	43,80	1	17
	100,		39

It may be represented thus

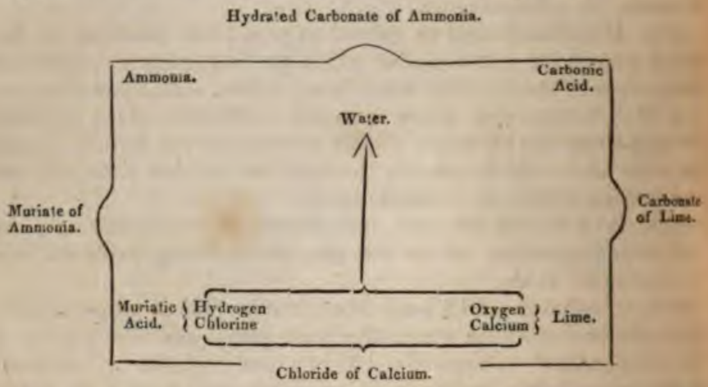


667. If water be present, it so far overcomes the elasticity of the gas, as to enable the salt formed to take up another volume of carbonic acid, and thus a *bicarbonate* is formed.

668. Carbonate of ammonia crystallizes in octoëdrons, though it is generally met with in cakes broken out of the subliming vessel, being obtained by sublimation from a mixture of muriate of ammonia and carbonate of lime.

The results, however, of this decomposition are not strictly speaking, carbonate of ammonia and muriate of lime, but carbonate of ammonia, water, and chloride of calcium, the two former being in combination, so that a *hydrated carbonate of ammonia* is always obtained.

Supposing the materials perfectly dry, the water is formed by the union of the hydrogen of the muriatic acid with the oxygen of the lime, as shown in the following diagram:



Sub-carbonate of ammonia.]

669. *Sub-carbonate of Ammonia—Sesqui-carbonate.* Mr Phillips has shown (*Journal of the Royal Institution*, vii. 294.) that the carbonate of ammonia of commerce (*ammoniæ sub-carbonas* of the Lond. Pharmacopœia) is a compound of

3 Proportionals of Carbonic acid	22	× 3	= 66
2 Ditto . . . . . . Ammonia	17	× 2	= 34
2 Ditto . . . . . . Water	9	× 2	= 18
			118

Viewing it as a compound of $1\frac{1}{2}$ proportions of carbonic acid, 1 ammonia, and 1 of water, it has been called by Mr Phillips a *sesqui-carbonate*, and if this view be unconnected with the notion of its containing the fraction of an atom, there can be no objection to the name. It is preferable, indeed, to that of sub-carbonate, which should be reserved for the compound, hitherto unknown, of 1 atom of acid and 2 of base.

Properties.

670. When the sesqui-carbonate is fresh prepared, it has a crystalline appearance and some transparency, and is hard and compact. It has a pungent smell, and a sharp penetrating taste, and affects vegetable blues as uncombined alkalies do. It dis-

solves in twice its weight of cold or an equal weight of boiling water. When exposed to the atmosphere, it loses weight very fast, ceases to be transparent, loses its odour, becomes brittle and easily reducible to powder; (H. 1. 409.) and ceases to act upon turmeric paper. In this state it may be considered as an *hydrated bicarbonate of ammonia*, and is composed, according to Phillips, of

2 Proportionals of Carbonic acid . . 22 × 2 = 44
1 Ditto . . . . . . Ammonia . . . . = 17
2 Ditto . . . . . . Water . . . . . 9 × 2 = 18
—
79 B.

It has therefore lost, by exposure, 1 atom of acid and one atom of base.

671. By varying the properties of the ingredients, and the regulation of the heat, it is possible to obtain a bi-carbonate at once by sublimation. (*Annals of Philos.* N. S. iii. 110.)

Union of carbon and chlorine.

672. *Carbon and Chlorine.*—Mr Faraday has ascertained that, by exposing carburetted hydrogen, mixed with great excess of chlorine, to the action of light, a white crystalline substance is formed, which, when purified by washing with water, is a *perchloride of carbon.*

Process.

673. To procure this substance a retort or other glass vessel of the capacity of about 200 cubic inches, provided with a brass cap and stop-cock, is first to be exhausted by the air-pump, and then made to communicate with a jar filled with chlorine. It is next to be screwed on a vessel full of olefiant gas, and as much as can find admission having entered, the cock is to be shut, and the whole left for a short time. When the fluid, composed of chlorine and olefiant gases, has formed and condensed on the sides of the vessel, the vessel is again to be placed over olefiant gas, and a further portion admitted. This process is to be repeated, till all the chlorine has united to form the fluid, and the vessel remains full of olefiant gas. Chlorine is then to be admitted by repeated portions, in consequence of which more of the fluid is formed, and ultimately a large portion is obtained, with an atmosphere of chlorine above it. The vessel is now to be exposed to the sun's rays, which cause the immediate formation of muriatic acid gas. This may be absorbed by admitting a small portion of water; and then another atmosphere of chlorine is to be introduced. Again exposed to the light, this will partly combine with the carbon, and partly form muriatic acid gas, which, being, as before, absorbed by water, leaves space for more chlorine. Repeating this action, the fluid gradually becomes thick and opaque, from the formation of crystals in it, which at last adhere to the sides of the vessel as it is turned round: and ultimately the vessel contains only chlorine, with the accumulated impurities of the gases; a strong solution of

muriatic acid coloured blue by its action on the brass; and the solid substance in question.

In order to cleanse the substance, the remaining gases are first to be blown out of the vessel by a pair of bellows, and the vessel is then to be filled with water to wash away the muriatic acid and other soluble matters. The new substance is then to be detached from the inside of the vessel, and poured with the water into a jar. A little alcohol will remove the last portions which adhere to the glass, and, when poured into the water, will precipitate the new compound, which must be collected on a filtre, and dried as much as possible by pressure between folds of bibulous paper. It must next be introduced into a glass tube, and sublimed by a spirit lamp. A part will be decomposed, but the sublimed portion is to be dissolved in alcohol, and poured into a weak solution of potash, by which the new substance is thrown down, and the muriatic acid neutralized and separated. Then wash away the potash and muriate by repeated affusions of water, until the substance remains pure; collect it on a filter, and dry it, first by pressure between folds of paper, and afterwards by sulphuric acid under the exhausted receiver of an air-pump. It will now appear as a white pulverulent substance; and, if perfectly pure, will not, when a little is sublimed in a tube, leave the slightest trace of carbon, or afford any muriatic acid. A small portion, dissolved in ether, should give no precipitate with nitrate of silver. If not quite pure, it must be re-sublimed, washed, and dried, as often as is necessary. H. 1. 350.

Properties. 674. This substance is nearly tasteless; its odour resembles camphor; its specific gravity is about 2; it is a nonconductor of electricity. It is volatile, and in close vessels fuses at 320°, and boils at 360°. It is not very combustible, but burns when held in the flame of a spirit lamp, with the emission of much smoke and acid fumes. It is insoluble in water, but readily soluble in alcohol and ether; these solutions deposit arborescent and quadrangular crystals. It also dissolves in volatile and fixed oils. It is scarcely acted upon by alkaline and acid solutions; but most of the metals decompose this substance at a red heat. Potassium burns brilliantly in its vapour, causing the deposition of carbon, and the production of chloride of potassium. The metallic oxides also decompose it at high temperatures, producing metallic chlorides, and carbonic acid or oxide, according to the proportion of oxygen present; no water is produced, showing the absence of hydrogen in the compound.

675. In forming this substance, Mr Faraday believes that five volumes of chlorine gas saturate one of olefiant, and produce four volumes of muriatic acid gas; that three volumes of the chlorine combine with the two volumes of charcoal existing in the olefiant gas to form the crystalline solid; and that when chlorine acts on the fluid compound of chlorine and olefiant gas, for every volume of chlorine that combines, an equal volume of

Composition.

hydrogen is separated. The results of its decomposition by per-oxide of copper, confirm these views, and tend to establish that the composition of per-chloride is

3 atoms of chlorine . . . . = 108
2 ditto of carbon . . . . = 12

Weight of its atom . . . 120. H. 351.

Proto-chloride of carbon.

676. When the above perchloride of carbon is passed through a red-hot tube, containing fragments of rock-crystal to increase the heated surface, it gives off a portion of chlorine, and is converted into a liquid *protochloride of carbon.* It is a limpid colourless fluid, specific gravity 1,55, and not combustible, except retained in the flame of the spirit-lamp, when it burns with a yellow flame, much smoke, and fumes of muriatic acid. It does not congeal at 0°; it rises in vapour at about 165°. It is insoluble in water, but soluble in alcohol, ether, and the oils. It is not affected by the acids or alkalies, nor at common temperatures, by solutions of silver. It dissolves chlorine, iodine, sulphur, and phosphorus. It affords, when decomposed, 17 carbon + 83 chlorine; whence it may be inferred to consist of

1 Proportional carbon . . . . . = 6
1 Ditto chlorine . . . . . = 36

42

Sub-chloride of carbon.

677. *Sub-chloride of Carbon.*—A third compound of chlorine and carbon was brought from Sweden by M. Julin, of Abo, where it had been accidentally formed during the distillation of nitric acid from crude nitre and sulphate of iron. The quantity produced at each process did not exceed a few grains, which condensed in fine white feathery crystals in a glass tube connecting the first and second receiver. Its properties are described by M. Julin as follows: (*Ann. of Phil.* N. S. i. 216.)

Properties.

678. It is white; consists of small soft adhesive fibres; sinks slowly in water; is insoluble in it whether hot or cold; is tasteless; has a peculiar smell, somewhat resembling spermaceti; is not acted upon by concentrated and boiling acids or alkalies, except that some of them dissolve a small portion of sulphur; dissolves in hot oil of turpentine and in alcohol, but most of it crystallizes in needles on cooling; burns in the flame of a lamp with a greenish blue flame, and a slight smell of chlorine; when heated melts, boils, and sublimes between 350° and 450° Fahr., or sublimes slowly at a heat of 250°, forming long needles. Potassium burns with a vivid flame in its vapour, and charcoal is deposited; and a solution of the residuum in nitric acid gives a copious precipitate with nitrate of silver.

679. A small quantity of this substance, having been put into the hands of Messrs R. Phillips and Faraday, has been made by them the subject of analysis. They found that it might

readily be purified from sulphur by boiling in liquid potash, washing in water, drying and subliming, when it formed beautiful acicular crystals, in the form of four-sided prisms.

Decomposition.

680. It was decomposed into chlorine and charcoal by being passed over red hot fragments of rock crystal. Its vapour, being detonated over mercury with excess of oxygen, gave carbonic acid gas and chloride of mercury. When heated with phosphorus, iron, or tin, chlorides of those substances were formed, and charcoal deposited. Its analysis was effected in two ways; by being transmitted over ignited peroxide of copper, and over dry quick-lime. Both processes gave results which conspire to show that it is constituted of

1 atom of chlorine	36
2 atoms of carbon	12
Weight of its atom	48

Messrs Phillips and Faraday have not given any name to this compound. It may be called, provisionally, the sub-chloride of carbon.

681. Thus we have three distinct compounds of chlorine and carbon, viz.

	At. of Chlor.		At. of Carb.
The per-chloride	3	+	2
The proto-chloride	1	+	1
The sub-chloride	1	+	2

It is probable that another chloride of carbon will hereafter be found, consisting of two atoms of chlorine and one of carbon. H. 1. 354.

Union with hydrogen.

682. *Carbon and Hydrogen—Carburetted Hydrogen—Olefiant Gas—Hydroguret of Carbon.*—Carbon and hydrogen combine and form olefiant gas, consisting of 1 proportional of carbon + 1 of hydrogen. Its composition will be

12 carbon }
2 hydrogen } two volumes of each condensed to one.

14

683. It is usually obtained by the decomposition of alcohol by sulphuric acid. For this purpose four parts of the acid and one of alcohol are put into a retort, and heated by a lamp. Soon after the mixture boils the gas is evolved. It may be collected over water; its specific gravity to hydrogen is 14. 100 cubic inches weigh 29.638 grains.

Properties.

684. This gas is inflammable, burning with a bright yellowish white flame. One part by volume requires, for perfect combustion, three of oxygen, and two of carbonic acid are produced. When sulphur is heated in one volume of this gas, charcoal separates, and two volumes of sulphuretted hydrogen result. As hydrogen suffers no change of volume by combining with sulphur, it follows that olefiant gas contains two

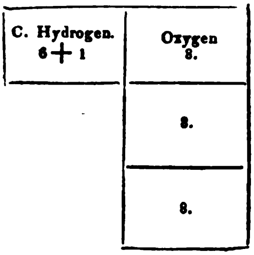
volumes of hydrogen condensed into one, hence the quantity of oxygen required for its combustion.

Decomposition.

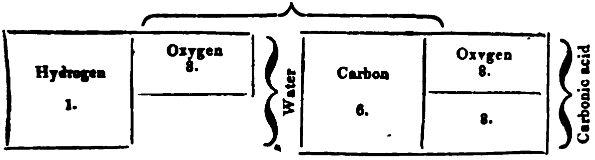
685. This gas is also decomposed by heat alone, as by passing and repassing it through a red-hot tube of earthenware or metal; it then deposits its carbon, and is expanded into twice its original volume of pure hydrogen.

686. The following symbols show that one volume or proportional of this gas, mixed with three of oxygen, are converted into water and carbonic acid, the hydrogen being expanded to two volumes, or its real bulk.

Before detonation.



After detonation.



This gas, therfore, is constituted of 1 proportional of carbon = 6 + 1 proportional of hydrogen = 1, and its number is 7.

Produces muriatic acid with chlorine.

687. When carburetted hydrogen is mixed with chlorine in the proportion of 1 to 2 by volume, the mixture on inflammation produces muriatic acid, and charcoal is abundantly deposited; but if the two gases be mixed in an exhausted vessel, or over water, they act slowly upon each other, and a peculiar fluid is formed, which appears like a heavy oil; hence this compound has been termed *olefiant gas*.

Chloric ether.

688. *Chloric ether* is the term applied to this fluid by Dr Thomson, who in 1810, ascertained that its component parts were chlorine and carburetted hydrogen. It has more lately been examined by M. M. Robiquet and Colin (*Annales de Chim. et Phys.* Vol. i. and ii.) The term *hydrochloride of carbon* may properly be applied to it. It may be formed by allowing a current of each gas to meet in a proper receiver; there should be excess of olefiant gas, for if the chlorine be in excess, the liquid absorbs it. It is transparent and colourless; its taste, sweet and somewhat acrid; its specific gravity = 1,2. It boils at 152°. It burns with a green flame, evolving muriatic acid, and largely depositing charcoal. As it is produced

by equal volumes of chlorine and carburetted hydrogen, it is probably a compound of one proportional of chlorine and two of carburetted hydrogen; or of

Chlorine	36
Carbon	12
Hydrogen	2
	50

689. From some recent experiments made at the Royal Institution by Mr Faraday, it appears that, by exposing this hydrochloride of carbon to the action of excess of chlorine, muriatic acid and chloride of carbon are the results.

Union with iodine.

690. When iodine and carburetted hydrogen are exposed to the action of light they combine, and form a *hydriodide of carbon*. This compound was first obtained in the Laboratory of the Royal Institution, by Mr Faraday; and, reasoning analogically upon the facts already stated, in respect to the chloride of carbon, it is probable that it may lead to the discovery of an *iodide of carbon*, but that compound has not as yet been formed.

The hydriodide of carbon is a white crystalline solid, volatile without decomposition, and in many respects analogous to the hydrochloride of carbon; its taste is sweet and its odour aromatic.

691. A gas, containing carburetted hydrogen, is often generated in stagnant ponds; and by passing the vapour of water over red-hot charcoal, or by distilling moist charcoal in an iron retort, at a red heat, and washing the gas thus afforded in lime-water, by which the carbonic acid is separated, a similar compound is said to be obtained.

The specific gravity of these gases is liable to great variation, 100 cubical inches weigh from 12 to 20 grains.

They burn with a paler flame, and require less oxygen than olefiant gas for perfect combustion.

692. It has generally been stated that these gases contain a definite compound of 1 proportional of carbon and 2 of hydrogen, to which the term *bi-hydroguret of carbon*, or *light hydrocarbonate* has been applied. From many experiments, however, on this subject, I* am induced to consider them as mixtures of olefiant gas and hydrogen, since I have never been able to obtain any other definite compound of carbon and hydrogen, than olefiant gas; and since they may be imitated by mixtures of olefiant and hydrogen gases, of the same specific gravities.

Coal gas.

693. These mixtures are abundantly produced during the destructive distillation of common pit-coal; and the gas thus obtained is employed for the purposes of illumination, as an economical substitute for tallow, oil, &c. The process is carried on upon a very extensive scale in Europe, in several public

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* Professor Brande.

and many private establishments. The coal is placed in oblong cast-iron cylinders, or retorts, which are ranged in furnaces to keep them at a red heat, and all the volatile products are conveyed by a common tube into a *condensing vessel*, kept cold by immersion in water; and in which the water, tar, ammoniacal, and other condensible vapours, are retained; the gaseous products consist principally of carburetted hydrogen, sulphuretted hydrogen, and carbonic oxide and acid; these are passed through a mixture of quicklime and water in vessels called *purifiers*, by which the sulphuretted hydrogen and carbonic gases are absorbed, and the carburetted hydrogen and hydrogen gases, transmitted sufficiently pure for use into *gasometers*, whence the pipes issue for the supply of streets, houses, &c. The coke remaining in the retorts is of a very good quality.*

694. The average specific gravity of purified coal-gas is 0,4500. 100 cubical inches weigh from 14 to 15 grains, and it may be considered as a mixture of about 55 volumes of hydrogen, and 45 of olefiant gas.

695. The best kind of coal for distillation is that which contains most bitumen and least sulphur. The chaldron should yield about 12000 cubical feet of purified gas, of which each Argand's burner, equal to six wax candles, may be considered as consuming from four to five cubical feet per hour.

696. The economy of gas illumination may be judged of by examining the value of the products of distillation of a chaldron of coals, the average cost of which may be considered as 3*l.* It should afford—

1¼	Chaldron of coke, at 25*s.*	1	11	3
24	Gallons of tar and ammoniacal liquor, at 3*d.*	0	6	0
12000	Cubic feet of gas, at 15*s.* per 1000 C.F. . . .	9	0	0
		£10	17	3

These products are taken at their lowest value, but they afford ample grounds for showing the advantage of gas illumination, not merely for public purposes, but also in private establishments, it appears that where more than fifty lights are required, a coal-gas apparatus will be found profitable.

Oil gas.

697. Messrs. J. and P. Taylor have lately constructed an apparatus for the conversion of oil into gas. It consists of a furnace with a contorted iron tube containing fragments of brick or coke, passing through it, into which, when red-hot, the oil is suffered to drop; it is decomposed, and converted almost entirely into charcoal, which is deposited in the tube, and into a mixture of carburetted hydrogen, and hydrogen gases, of which

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* Mr Parker, of Liverpool, (*Phil. Mag.* Vol. lii. p. 292,) has proposed to pass the gas as it comes from the coal retorts through red hot iron tubes, by which the contaminating gases and vapours are urther decomposed, and the quantity of useful gas much increased. This suggestion, if it succeeded, would greatly diminish the quantity of tar, which is the only useless product; but as carburetted ydrogen is decomposed at a red heat, it will obviously tend to diminish the illuminating power of the as, though it will increase its quantity.

from two to three cubic feet may be regarded as equivalent to five or six of coal-gas, for the production of light.—*Quarterly Journal*, Vol. viii.*

The commonest whale oil, or even pilchard-dregs, quite unfit for burning in the usual way, afford abundance of excellent gas, requiring no other purification than passing through a refrigerator to free it from a quantity of empyreumatic vapour.

698. A gallon of whale-oil affords about 100 cubical feet of gas, and an Argard burner, equal to seven candles, consumes a cubical foot and a half per hour. The cost of a lamp fed by oil or coal gas, and giving the light of seven candles will be 3 farthings per hour.

Of Argand's lamp with spermaceti oil	3*d.*
Mould-candles	3½
Wax-candles	14

699. By a series of experiments, conducted with every requisite caution (*Phil. Trans.* 1820, p. 23.) Professor Brande found that, to produce the light of ten wax candles for one hour, there were required

2600	cubical inches of pure carburetted hydrogen or olefiant gas.
4865	oil gas.
13120	coal gas.†

700. The fitness of the gas obtained from coal for the purposes of illumination, is, *ceteris paribus*, dependent upon the quantity of carburetted hydrogen, or olefiant gas, which it contains; and, consequently, the fitness of the purified mixed gas for illumination, will be directly as its specific gravity; or, the relative proportion of olefiant gas, may be judged of by mixing the purified coal gas with twice its volume of chlorine over water, by which the olefiant gas will be absorbed, and its quantity shown by the amount of the absorption which takes place.

701. Experiments, thus conducted, show that purified *coal gas* seldom contains more than 40 *per cent.* in volume of carburetted hydrogen, while *oil gas* generally affords about 75 *per cent.;* hence its superiority for burning, and the relatively small quantity consumed.

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* A convenient apparatus for obtaining oil gas, in sufficient quantity for the exhibition of its properties, is represented by fig 117. *a* is a vessel of cast iron about 16 inches in depth, and 6 in diameter at its upper part; having a cast iron cover, with two openings, to the smallest of which, a copper pipe leading from a funnel-shaped oil vessel *b*, is secured by brazing; into the larger opening a gun barrel *c* is screwed which enters a small copper condensing vessel *d* furnished with a cock for drawing off any oil, or condensible vapors that may pass over. From the upper part of the condenser a copper or lead pipe issues, which conveys the gas to a gasometer. When oil gas is to be obtained, the vessel *b* is filled with oil, and the pieces of bricks are put into the retort *a*, the cover is then secured by a rod of iron passing through the ears *e e*, and the joint is made tight by a mixture of about 2 parts of muriate of ammonia, 1 of sulphur and 30 of cast iron filings or borings, made into a paste with water.* This retort may be placed in any convenient furnace, and when heated to redness the cock *f* is turned so as to allow the oil to pass drop by drop.

† It seems probable that the coal gas, employed in these experiments, was below the general standard, and that it was a fair average to consider one vol. of oil gas as equivalent to 2 or at most 2½ volumes of gas from coal of good quality. H.

* This cement should be allowed to become hard before the apparatus is used.

Dr Henry (*Phil. Trans.* 1808,) has given some important experiments upon the production of gas from coal, by which it appears that its composition is various at different stages of the distillation. The mode of distillation also affects the quantity and quality of the products.

702. An account of the apparatus for the production of coal gas, and of its construction and expense, will be found in the *Treatises on Gas Lights*, by Mr Accum and Mr Peckston.

703. A mixture of carburetted hydrogen and hydrogen is contained abundantly in coal strata, from fissures in which it is sometimes evolved in large quantities, forming what in the language of the north country miners, is called a *blower*. When this gas is accumulated in any part of the gallery or chamber of a mine, so as to be mixed in certain proportions with common air, the presence of a lighted candle, or lamp, causes it to explode, and to destroy, injure, or burn whatever is exposed to its violence. The miners are either immediately killed by the explosion, and thrown with the horses and machinery, through the shaft into the air, the mine becoming as it were an enormous piece of artillery from which they are projected; or they are gradually suffocated, and undergo a more painful death from the carbonic acid and nitrogen remaining in the mine, after the explosion of the *fire damp;* or what, though it appears the mildest, is perhaps the most severe fate, they are burned or maimed, and often rendered incapable of labour and of healthy enjoyment for life.—Davy, *on the Safety-Lamp for Coal Miners*, London, 1818.

Sir H. Davy, in the treatise just quoted, has given a sketch of different, but ineffectual. contrivances of others, for the prevention of these dreadful, and hitherto frequently occurring, accidents; and has described the train of investigation by which he was led to the discovery of a remedy at once simple and efficient, and which has already been submitted to repeated and successful trials. Safety lamp.

704. The properties of flame, and the principle of safety adopted in this lamp, have already been adverted to (182). It is obvious, from what has there been said, that if the flame of a common lamp be every where properly surrounded with a wire-gauze, and in that state immersed into an explosive gaseous mixture, it will be inadequate to its inflammation, that part only being burned which is *within* the cage, communication to the inflammable air *without* being prevented by the cooling power of the metallic tissue; so that by such a lamp the explosive mixture will be consumed, but cannot be exploded.

705. Fig. 118 is a representation of the safety lamp, as recommended for general use by Sir H. Davy. *a* is a cylinder of wire gauze, with a double top, securely and carefully fastened, by doubling over, to the brass rim *b*, which screws on the lamp *c*. The whole is protected and rendered convenient for carrying, by the frame and ring *d*. If the cylinder be of twill-

ed wire-guaze, the wire should be at least of the thickness of one-fortieth of an inch, and of iron or copper, and 30 in the warp, and 16 or 18 in the weft. If of plain wire gauze, the wire should not be less than one-sixtieth of an inch in thickness, and from 28 to 30 both warp and woof.—DAVY, *on the Safety Lamp*, p. 114, *et seq.*

Exp. The operation of this lamp may be shown on a small scale by suspending it in a glass jar, and then admitting a sufficient stream of coal gas to render the enclosed atmosphere explosive. The flame of the lamp first enlarges, and is then extinguished, the whole of the cage being filled with a lambent blue light; on turning off the supply of the gas this appearance gradually ceases, and the wick becomes rekindled, when the atmosphere returns to its natural state.

When a small coil of platinum wire is hung above the wick of the lamp within the wire gauze cylinder, the metal continues to glow, long after the lamp is extinguished, and affords light enough to guide the miner in what would otherwise be impenetrable darkness. In this case the combustion of the fire damp is continued so slowly, and at so low a temperature, as not to be adequate to that ignition of gaseous matter, which constitutes flame, though it excites a temperature sufficient to render platinum wire luminous.

As the *safety* of these lamps entirely depends upon the perfect state of the wire gauze, and upon the non-existence of any aperture or channel sufficiently large to admit of the passage of flame, they should, when used in a coal mine, be inspected daily to ensure their soundness in these respects.

Method of analysing mixtures of carburetted hydrogen, &c.

706. The analysis of a mixture of hydrogen with carburetted hydrogen, carbonic oxide, and carbonic acid, presents peculiar difficulties in the ordinary mode of proceeding; and as it often requires to be performed in investigations relating to the gases used for illumination, it became an object to facilitate the process, for which I have used the following plan. (BRANDE.)

A hundred measures of the gas are introduced into a graduated tube, and the carbonic acid absorbed by a solution of potassa; the remaining gas is then transferred to thrice its volume of chlorine of known purity, standing over water in a tube of about half an inch in diameter, and exposed to daylight, but carefully excluded from the direct solar rays; after 24 hours the carburetted hydrogen and the excess of chlorine will have been absorbed, and the remaining gas, consisting of carbonic oxide and hydrogen, may be analyzed by detonation with oxygen in excess; the measure of carbonic acid formed being equal to that of the original carbonic oxide.

This proceeding depends upon the non-formation of chlorocarbonic (642) acid in a mixture of carbonic oxide and chlorine in the contact of water, and out of the direct agency of the solar rays. Such mixture has been kept several days, occasionally renewing the chlorine as it became absorbed by the water, and on diminution in the bulk of the carbonic oxide has been observed. In all these cases it is necessary to ascertain the purity of the chlorine by its absorption by water, and to be aware of the evolution of common air from water during that process.

Bi-carburet of Hydrogen.

707. When oil gas is compressed a colourless fluid is deposited, which is nearly insoluble in water, but soluble in alcohol, ether and oils. It burns with a dense flame, and is distinguished from the oil from which it originated, by not being acted upon to any extent, by solutions of alkalies. Part of this fluid is volatile at 60°, while other parts are more fixed. By repeated distillations Mr Faraday obtained from it a series of products from the most to the least volatile. These were subjected to a low temperature, and some of them concreted into a crystalline mass, and a substance was ultimately obtained, principally by pressure at low temperatures, which proved to be a new compound of carbon and hydrogen. At common temperatures it is a colourless liquid, of specific gravity 0,85 at 60°, and has the odour of oil gas. Below 42° it is a solid body forming dendritical, transparent crystals. At 0° it appears white or transparent, brittle, pulverulent, and of the hardness nearly of loaf-sugar. It evaporates entirely in the air: at 186° it boils, furnishing a vapour, which has a specific gravity of 40 nearly compared to hydrogen as 1. At a higher temperature the vapour is decomposed, depositing carbon. It is combustible, liberating charcoal, if oxygen be not abundantly present.

Analysis.

708. This substance was analysed by being passed over red-hot oxide of copper, and by detonation of its vapour with oxygen, and was found to consist of

2	proportionals of carbon	12
1	" hydrogen	1
		13

And in the state of vapour one volume was found to consist of 6 proportionals of carbon and 3 of hydrogen = 39.

It has been called by Mr Faraday *Bi-carburet of hydrogen.*

709. From the more volatile portions of the fluid Mr Faraday obtained a product, which, though gaseous at common temperatures, condensed into a liquid at 0°. It was very combustible, and constant in composition and properties. Its sp. gr. was 27 or 28 in its gaseous state; as a liquid 0,627; being the lightest substance, not a gas or vapour, known. It was found to consist of 1 proportional of carbon = 6, + 1 of hydrogen = 1, as is the case with olefiant gas; but these are so condensed and combined, as to occupy only one half the volume they do in that substance. A volume therefore of this gas contains 4 proportionals of carbon = 24 + 4 of hydrogen = 28, which is its specific gravity.

710. Besides the remarkable difference, thus established, between this substance and olefiant gas, it is also distinguished by the action of chlorine, with which it forms a fluid body having

a sweet taste, and resembling hydro-chloride of carbon; but from which a chloride of carbon cannot be obtained by the further action of chlorine and light.

Uses.

711. The fluid as originally obtained when put into gas burning with a blue flame, makes it produce a bright white flame; it is an excellent solvent of caoutchouc, and will answer all the purposes to which essential oils are applied as solvents. (See *Philosophical Magazine*, lxvi. 73).

Union with Nitrogen.

712. *Carbon and Nitrogen—Carburet of Nitrogen—Cyanogen.*—This gaseous compound was discovered by Gay-Lussac in 1815. (*Annales de Chimie*, xcv.)

Process for obtaining cyanogen.

To obtain cyanogen, it is necessary first to boil fine powdered red oxide of mercury with twice its weight of prussian blue and a sufficient quantity of water. The compound is perfectly neutral, and crystallizes in long four-sided prisms truncated obliquely. It still, however, contains a little iron, which may be separated by digesting the liquor, before evaporation, with a little more of the oxide of mercury, and saturating the excess of this oxide with a little prussic acid, or even with a little diluted muriatic acid. The prussiate of mercury, thus obtained neutral and crystallized, must be carefully and completely dried at a temperature below that of boiling water, and then exposed to heat in a small glass retort, or in a tube closed at one extremity. It first blackens, then liquefies, and the cyanogen comes over in the form of a gas, which may be collected over mercury. In the retort there remains a charry matter of the colour of soot, and as light as lamp black.*

Properties.

713. Cyanogen is a true gas, or permanently elastic fluid. Its smell is strong, penetrating, and disagreeable, resembling that of bitter almonds. It burns with a bluish flame mixed with purple. Its specific gravity is to that of hydrogen as 26 to 1; to common air as 1,8064 (1,8055, T.) to 1.† 100 cubic inches at 60° Fahr. weigh 55 grains.

714. Water at the temperature of 60° Fahr. absorbs almost 4' times its volume, and pure alcohol 23 times its volume. The watery solution reddens litmus; this, however, is scarcely to be considered as an effect of cyanogen, but of the products to which it gives rise by the decomposition of water. (VAUQUELIN in *Ann. of Phil.* xiii. 430.) H. 1. 439.

The aqueous solution, according to Vauquelin, (*Annales de Chim.*, Oct. 1818,) is subject to spontaneous decomposition, being gradually converted into carbonic and hydrocyanic acids, ammonia, a peculiar acid which he calls the *cyanic*, and a brown substance containing carbon; the ammonia saturates the acids, and the carbonaceous compound is deposited. These changes are referable to the mutual re-action of the elements of cyanogen upon those of water.

Analysis.

715. Cyanogen may be analyzed by detonation with oxygen. One volume, detonated over mercury with two of oxygen, pro-

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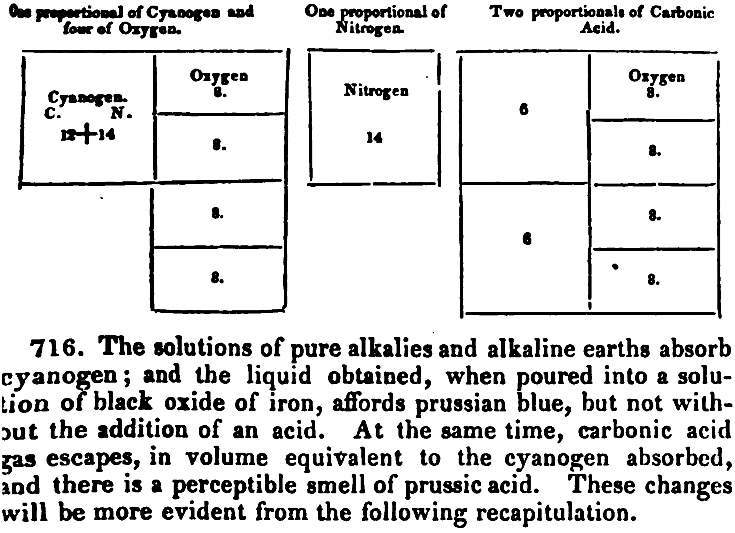
* Gay-Lussac, Ann. de Chim. Vol xcv.; or Thomson's Annals, viii. 37.

† Its specific gravity, Oxygen, = 1 is 1,625. T.

duces two volumes of carbonic acid, and one of nitrogen. Whence it appears that cyanogen consists of two proportionals of carbon = 12, and 1 of nitrogen = 14, the nitrogen having suffered no change of bulk by uniting with the carbon; or it may be said to consist of two volumes of gaseous carbon + one volume of nitrogen, the three being condensed into one volume. Its representative number is 26.

The following symbols exhibit the mixture of cyanogen with oxygen in the above proportions, and the result of their detonation:

Before detonation. After detonation.


One proportional of Cyanogen and four of Oxygen.
One proportional of Nitrogen.
Two proportionals of Carbonic Acid.
Cyanogen.
C. N.
12+14
Oxygen 8.
8.
8.
8.
Nitrogen
14
6
6
Oxygen 8.
8.
8.
8.

Absorbed by alkaline solutions, &c.

716. The solutions of pure alkalies and alkaline earths absorb cyanogen; and the liquid obtained, when poured into a solution of black oxide of iron, affords prussian blue, but not without the addition of an acid. At the same time, carbonic acid gas escapes, in volume equivalent to the cyanogen absorbed, and there is a perceptible smell of prussic acid. These changes will be more evident from the following recapitulation.

1 vol. of cyanogen {= 2 vols. charcoal and 1 vol. nitrogen} decomposes 1 atom of water {= 1 vol. oxygen and 2 vols. hydrogen.

One volume of charcoal, uniting with one volume of oxygen, forms one volume of carbonic acid; the remaining volume of charcoal, uniting with half a volume of nitrogen and half a volume of hydrogen, composes prussic acid; and the residuary half volume of nitrogen and 1½ volume of hydrogen compose together one volume of ammonia.

717. When to two volumes of charcoal and one volume of nitrogen, together constituting cyanogen, one volume of hydrogen is joined, and the whole four volumes are condensed into two, we obtain *prussic* or *hydro-cyanic acid.* Cyanogen agrees then with chlorine and iodine, in being acidifiable by union with hydrogen. Hence its compounds with metallic bases have been called by Gay-Lussac *cyanures* as those of chlorine are called *chlorures.* H. 1. 441.*

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* The term *cyanides* is preferable, and in more general use.

Union of cyanogen and chlorine.

718. *Cyanogen and Chlorine* combine and produce the *Chlorocyanic acid.* M. Gay-Lussac procured this compound by passing a current of chlorine through a solution of hydrocyanic acid (722) in water, till the liquid discoloured a diluted solution of indigo in sulphuric acid. He then deprived it of excess of chlorine by agitation with mercury. To separate chlorocyanic acid from this liquid, he took a glass cylinder, filled it two thirds with mercury, and then to the brim with the above liquid, and inverted it in a basin of mercury. This basin and cylinder were put under the receiver of an air-pump, and the air drawn out, till the mercury and liquid were displaced; the cylinder became filled with the vapour of chlorocyanic acid; on admitting the air, the vapour condensed into a liquid, and the mercury rose in the cylinder. It may also be obtained by carefully distilling the liquid into a receiver surrounded by ice.

Properties.

719. Chlorocyanic acid thus obtained is a colourless and very volatile liquid, having a peculiar and irritating odour. It reddens litmus; is not inflammable; and does not form detonating mixtures either with oxygen or hydrogen.

720. According to the analysis of Gay-Lussac, this acid is constituted of

$$\left.\begin{array}{l}\text{1 vol. of gaseous carbon}\\ \tfrac{1}{2}\text{ a volume of nitrogen}\\ \tfrac{1}{2}\text{ `` \quad `` \quad `` chlorine}\end{array}\right\}\text{ condensed into 1 volume.}$$

In other words 1 vol. of chlorine, and 1 vol. of cyanogen produce by combining 2 vols. of chlorocyanic acid. Hence its density should be the mean of those of its components. H. 1. 446.

The following symbols represent its composition and volume

Cyanogen	Chlorine	Chlorocyanic Acid.
26,0	36	62

Union of cyanogen and iodine.

721. *Iodine and Cyanogen* form a volatile solid compound, which collects in flocculi, and has an acrid taste and pungent smell; it may be formed by heating iodine with cyanuret of mercury.—Davy. *Quart. Journal*, i. 289.

Union of cyanogen and hydrogen.

722. *Cyanogen and Hydrogen—Hydrocyanic* or *Prussic acid.*—This triple compound may be obtained by moistening cyanuret of mercury with muriatic acid, and distilling at a low temperature, having surrounded the receiver with ice.

723. A liquid is thus obtained which has a strong pungent odour, very like that of bitter almonds; its taste is acrid, and it is highly poisonous. When a rod dipped in concentrated prussic acid is brought in contact with the tongue of an animal, it expires before the rod can be withdrawn. Its vapour occa-

sions nausea, headache and faintness. (See BIGELOW's *Sequel to U. S. Pharmacopœia*, p. 49.) It volatilizes so rapidly as to freeze itself. It reddens litmus.

Preparation.

724. The hydrocyanic acid is used in medicine, and several formulæ have been given for its preparation; the following affords the acid of a convenient strength, and is that which is adopted at Apothecaries' Hall, (Lond.) One pound of cyanuret of mercury is put into a tubulated retort with six pints of water, and one pound of muriatic acid, specific gravity 1,15; a capacious receiver is luted to the retort, and six pints are distilled over. The specific gravity of the product is 0,995.*

Vauquelin's method.

725. M. Vauquelin's method of preparing dilute hydrocyanic acid, consists in passing sulphuretted hydrogen through a solution of cyanuret of mercury, which, when decomposed, is to be filtered and mixed with carbonate of lead, in order to separate the excess of sulphuretted hydrogen. As this acid in its dilute state suffers partial decomposition by keeping, it should be prepared in small quantities only for pharmaceutical use, and preserved in vessels excluded from light.

Gaseous hydrocyanic acid.

726. Hydro-cyanic acid may also be collected in a gaseous form over mercury, by heating in a retort the crystallized ferrocyanate of potash with dilute sulphuric acid. This gas is absorbable by water and alcohol. It is speedily fatal when received into the lungs of small animals. At a temperature between 86° and 95° Fahrenheit, the acid gas forms with oxygen gas a mixture which detonates on passing an electric spark. A quantity equal to 100 measures condense 125 measures of oxygen, and there result 100 measures of carbonic acid and 50 measures of nitrogen. But as the carbonic acid contains only its own volume of oxygen, there remain 25 measures of the latter gas which must have been converted into water by 50 measures of hydrogen existing in the prussic acid vapour. From these and other facts, Gay-Lussac infers that it is composed of one volume of the vapour of charcoal, half a volume of hydrogen, and half a volume of nitrogen, condensed into one volume.

Composition.

727. When potassium is heated in hydro-cyanic vapour, it evolves hydrogen gas equal to half the volume of the vapour. The other elements of the gas unite with the potassium. Thus he hydro-cyanic acid is resolved into hydrogen and cyanogen, which last, uniting with the potassium, forms a cyanide of that metal. As hydro-cyanic acid is constituted of equal volumes of hose two gases, united without condensation, the specific gravty of the acid gas ought to be the mean of those of its components, viz. 0,9360 very nearly. This differs very little from the

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* The specific gravity of the acid is considered by Dr Ure as an inadequate test of its strength; and he recommends the following as a more simple method of analysis. "To 100 grains, or any other convenient quantity, of the acid, contained in a small phial, add, in succession, small quantities of he peroxide of mercury in fine powder, till it ceases to be dissolved on agitation. The weight of the oxide taken up, being divided by four, gives a quotient representing the quantity of real prussic acid present. By weighing out beforehand on a watch glass 40 or 50 grains of the peroxide, the residual weight of it shows at once the quantity expended." (*Quarterly Journal*, xiii. 312.)

result of experiments, viz. 0,9476. Its constituents, therefore, are by weight

Cyanogen	100
Hydrogen	3,846

or two atoms of charcoal = 12 + 1 of nitrogen = 14 + 1 of hydrogen, and its equivalent number is 27.

Union with sulphuretted hydrogen.

728. The salts formed by the union of this acid with salifiable bases are called *hydro-cyanates*, but they are not permanent, and have no useful properties. They are decomposed by the weakest acids, such as the carbonic. H. 1. 443.

729. It appears from the experiments of Mr Porrett (*Phil. Trans.* 1814,) and from those of M. Gay-Lussac (*Ann. de Chim.* xcv.) that cyanogen is capable of forming a compound with sulphuretted hydrogen. It may be obtained by mixing one volume of cyanogen with one and a half of sulphuretted hydrogen; they slowly combine, and form a yellow crystallized compound.

730. According to Dr Thomson, Mr Porrett obtained an analogous body by a much more circuitous process; he has termed it *sulphuretted chyazic acid;* and Dr Thomson, who regards it as consisting of cyanogen and sulphur only, calls it *Sulphocyanic acid.*—(*Syst.* V. ii. p. 290.) He describes it as soluble in water; of a smell resembling vinegar; and decomposed by repeated distillation. (*See a paper in the Jour. de Pharmacie, Oct.* 1818.—*Also, Ann. Philos.* Vol. xiii. 101.)

731. Sir H. Davy has noticed the production of a compound of sulphur and cyanogen, obtained by heating a mixture of sulphur and cyanuret of mercury; and by heating phosphorus with cyanuret of mercury, a *cyanuret of phosphorus* appears to be formed.

Sulphuret of Carbon.

732. *Carbon and Sulphur—Sulphuret of Carbon Alcohol of Sulphur.*—This is a liquid obtained by passing sulphur over red hot charcoal.

Process for preparing.

733. To prepare it, a coated earthen tube, of about one inch and a half in diameter, partly filled with small pieces of charcoal, well prepared, and quite free from moisture, may be disposed in a furnace, as represented fig. 119, one end being placed higher than the other. To this end may be adapted a glass tube, open at both ends, containing small bits of sulphur; and to the other end, by means of an adopter, is to be fixed a curved tube, passed into water contained in a two-necked bottle. The part of the tube, containing the charcoal, may then be made red hot; and, when this happens, the bits of sulphur are to be pushed forwards, one by one, by means of a wire, carefully excluding the air. As soon as the sulphur comes into contact with the charcoal, bubbles of gas will be produced in great abundance, and a vapour will appear, which will condense, under the water in the bottle, into a liquid, of which, in the course of a day, about half a pint may be procured. This liquid may be purifi-

ed by re-distilling it at a very gentle heat, not exceeding 100° or 110° Fahrenheit; and some dry chloride of calcium may be put into the retort, in order to obtain the fluid perfectly free from water. The liquid which comes over is quite pure, and some sulphur remains in the retort. It may also be obtained by distilling a mixture of ten parts of finely pulverized and perfect charcoal with 50 of native bi-sulphuret of iron, from an earthen retort into a receiver surrounded by ice or snow. One part of sulphuret of carbon will be obtained from these materials. H. 1. 452.

Properties.

734. The alcohol of sulphur has the following properties. It is eminently transparent, and perfectly colourless. Sometimes, immediately after distillation, the oily liquid appears a little opaque and milky; but the next day it is found to have become completely limpid. It has an acrid, pungent, and somewhat aromatic taste; its smell is nauseous and fetid, though differing from that of sulphuretted hydrogen. It is insoluble in water, but soluble in alcohol and ether; its refractive power in regard to light is very considerable. Its specific gravity is 1,272. It boils at 106°, and does not freeze at—60°. It is very volatile, and has a pungent taste and peculiar fetid odour. The cold which it produces during evaporation is so intense, that by exposing a thermometer bulb, covered with fine lint, and moistened with it, in the receiver of an air-pump, the temperature sunk, after exhaustion to — 80°. When a mercurial thermometer was used, the metal froze.

735. Sulphuret of carbon is inflammable, and when burned with oxygen, produces sulphurous and carbonic acids. It consists of 1 proportional of charcoal and 2 of sulphur; $6 + 32 = 38$. (Berzelius and Marcet, *Phil. Trans.* 1813.) It was discovered by Lampadius, who called it *Alcohol of Sulphur.*—Crell's *Annals*, 1796, ii.

736. A portion of carburet of sulphur appears to be frequently formed during the production of inflammable gas from coal (693), and to be retained in the state of vapour by the gas after its purification by lime, such gas gives a strong sulphurous smell when burned, although perfectly cleansed from sulphuretted hydrogen.—Brande, *Phil. Trans.* 1820, p. 19.

Decomposition.

737. When transmitted over ignited copper or iron turnings, alcohol of sulphur is decomposed, the metal combining both with charcoal and sulphur; and a rose coloured fluid is obtained, differing in its sensible qualities from the original liquid, and apparently consisting of the same elements in different proportions. It is decomposed also when brought into contact with ignited peroxide of iron; sulphuret of iron is formed; and sulphurous and carbonic acids are produced, and may be separated from each other by borax, which absorbs the former only. In this way it may be analyzed, and its proportions calculated.

Composition. 738. The proportions of the elements of sulphuret of carbon are deduced by Berthollet, Thenard, and Vauquelin, to be from 14 to 15 parts of charcoal, and from 85 to 86 of sulphur, in 100. This statement of its composition nearly agrees with that determined by Drs Berzelius and Marcet; *viz.*

Sulphur	84,83	or	100,
Carbon	15,17		17,89
	100		117,89

The above-mentioned numbers establish the proportion of the elements of this compound to be two atoms of sulphur = 32 to one of carbon = 6, and its equivalent number to be 38.

739. It has been found also by Mr Murray, that when a few drops of this liquid are poured on the surface of a glass of water, the temperature of which is 32° Fahr., plumose branches of ice dart from the sulphuret to the bottom of the vessel, and the whole water is suddenly frozen. At the same time, the sulphuret becomes volatilized; and the spiculæ of ice beautifully exhibit the colours of the solar spectrum. (*Ann. of Philos.* iii. N. S.) H. 1. 454.

Union with phosphorus. 740. *Carbon and Phosphorus—Phosphuret of Carbon.*—To obtain this compound, Dr Thomson directs the following process: (*System* i. p. 276.) Allow phosphuret of lime to remain in water, till it no longer evolves gas; then add to the liquid excess of muriatic acid, agitate for a few moments, and throw the whole upon a filter. Phosphuret of carbon remains, which is to be washed and dried. This compound is a soft powder, of a yellowish colour, without taste or smell: exposed to air, it slowly imbibes moisture, and acquires an acid flavour. Exposed to a red heat, it burns, and gradually gives out its phosphorus, the charcoal being prevented burning by a coating of phosphoric acid. It consists of phosphorus 0,62 + carbon 0.38 (Thomson's *Annals.* viii. 157.) These numbers closely correspond with

Phosphorus	1 proportional	= 12
Carbon	1 ditto	= 6
		18

It would appear from the mode of obtaining this phosphuret, that it forms an ingredient in phosphuret of lime, as usually prepared.

Hydroxanthic acid. 741. *Sulphuret of Carbon and hydrogen—Hydroxanthic or Carbo-sulphuric acid.*—When bi-sulphuret of carbon (732) is gradually added to a solution of pure potassa, in alcohol containing 96 or 98 *per cent.* pure alcohol, and the mixture is agitated, the alkali is completely neutralized by the formation of a new acid. This new acid contains sulphur, carbon and hydrogen, the two first of which probably form a compound base, analogous to cyanogen, and, like it, acidifiable by hydrogen. To the base, Mr Zeise, Professor of chemistry at Copenhagen, who first noticed these facts, has given the name of *xanthogene* (from ξανθος, yellow, and γενναω, to generate) on account of the yellow colour of its compounds; and to the acid that of *hydroxanthic acid.*

Hydroxanthate of Potash.

742. The neutral solution, obtained in the above manner, may be made to deposit crystals by lowering its temperature to the freezing point, or by exposing it under an exhausted receiver along with sulphuric acid. These crystals are the *hydroxanthate of potassa.* They are needle-shaped; without colour, except after exposure to the air, which renders them yellow; have a peculiar odour; a taste at first cooling, and then sharp and sulphurous; are extremely soluble in water, though not deliquescent; in a less degree in ether; and not at all in naphtha. The watery solution becomes milky when exposed to the air, and soon manifests an excess of alkali. Sulphuric or muriatic acid, diluted with four or five parts of water, and added in due quantity to the watery solution, occasion no effervescence, but cause the separation of an oily looking fluid heavier than water. This is the *hydroxanthic acid.*

743. Solution of baryta in water or in acids, muriate of lime, and sulphates of magnesia or alumina, do not affect the hydroxanthate of potassa; but several metallic salts occasion precipitates, which are compounds not of the metallic oxides with the new acids, but of the metals with xanthogen. Hence M. Zeise proposes to call them *xanthures;* but it is more consistent with the nomenclature followed in this work to term them *xanthides*, analogous to *chlorides*, *cyanides*, &c. Several of the xanthides are described by their discoverers.

744. The *hydroxanthate of potassa* is decomposed when distilled *per se*, and yields an oily fluid, with a gas which has the smell of onions, but in which nothing could be discovered but carbonic acid and sulphuretted hydrogen. At a red heat, in the open air, it takes fire, and is consumed tranquilly with a bluish flame, but in the flame of a candle it burns actively, emitting bright sparks.

— of Soda.

745. Hydroxanthates of soda and ammonia may be prepared with alcoholic solutions of those alkalies and bi-sulphuret of carbon; those of baryta and lime with hydroxanthic acid and their respective carbonates. The salt, with base of soda, is a little deliquescent.

Properties of Hydroxanthic acid.

746. Hydroxanthic acid, separated by more powerful acids from its saline compounds, with some precautions which M. Zeise has pointed out, is liquid at common temperatures, and even below them; it has the aspect of a transparent colourless oil;

in specific gravity it exceeds water; and it is not miscible with that fluid. Exposed to the air, it soon becomes covered with a white opaque crust. Its smell is powerful and peculiar. It has a taste at first acid, then astringent and bitter; litmus paper is completely reddened by it, but a part of the paper soon changes to a yellowish white. It is inflammable, and burns with a smell of sulphurous acid. A temperature below 212° decomposes it into bi-sulphuret of carbon and a combustible gas. When much divided by agitation with water, it is decomposed in a short time, giving out bubbles of gas. It expels carbonic acid from alkaline carbonates. The oxides of common metals (copper, lead, mercury, &c.) decompose it by giving up their oxygen to the hydrogen of the acid, and the xanthogene unites with the metal forming *xanthides.*

747. The presence of hydrogen in hydroxanthic acid was established by the results of acting upon it with iodine, which occasioned a distinct production of hydriodic acid, a compound of iodine and hydrogen. (*Annales de Chim. et de Phys.* xxi. 160, and *Ann. of Phil.* N. S. iv. 241.) H. ii. 667.

SECTION VI. *Boron.*

How discovered.

748. Boron was first obtained by Sir H. Davy in 1808, by the action of Voltaic electricity on boracic acid. When that acid slightly moistened with water, was exposed between two surfaces of platina to a battery of 500 pairs of plates, an olive brown matter began immediately to appear on the negative surface, and gradually increased in quantity. This substance was found not to be acted on by water, but to dissolve with effervescence in warm nitric acid. When heated to redness on platina, it burned slowly, and boracic acid was regenerated. Hence the name of *boron* has been applied to it. H. 1. 355.

Mode of obtaining.

749. This substance is also obtained by heating in a copper tube two parts of the metal called potassium, with one of boracic acid previously fused and powdered. In this experiment the boracic acid, which consists of boron and oxygen, is decomposed by the potassium. The fused matter is washed out of the tube with water, and the whole put upon a filter. The boron remains in the form of a brown, insipid, insoluble powder, unaltered by exposure to air at common temperatures, but when heated to 600° it burns with much brilliancy, especially in oxygen gas, and produces *boracic acid.* It is a non-conductor of electricity.

Boracic acid.

750. Boracic acid is usually obtained by dissolving the salt called *borax* in hot water, and subsequently adding half its weight of sulphuric acid; as the solution cools, white scaly crystals appear, which, when washed with cold water are nearly

tasteless, and which consist of boracic acid combined with water and retaining a little sulphuric acid, which it loses by exposure to a strong red heat, and fuses into a glass.

Boracic acid is very difficultly soluble in water; the solution reddens vegetable blues, but possesses the singular property of rendering the yellow of turmeric brown, in the manner of an alkali. Its solution in spirit of wine burns with a green flame. wine burns with a green flame. This acid was first obtained by Homberg, in 1702, and was used in medicine, under the name of *Homberg's Sedative Salt*. Its nature was first shown by Davy.

Composition.

751. The experiments upon the composition of boracic acid are much at variance. Berzelius's determination probably appears nearest to truth: He regards it as containing 1 boron + 3 oxygen. (THOMSON'S *System*, Vol. i. p. 249, 5th edit.) If, therefore, we consider it as consisting of 1 proportional of boron and 2 of oxygen, the number representing boron will be 6, and boracic acid will consist of

1 Boron	6
2 Oxygen	16
Boracic acid	22

Native.

752. *Native boracic acid* has been found in the Lipari islands, and also in the hot springs of Sasso, in the Florentine territory; hence the term *Sassolin* applied to it by some mineralogists.

Union with ammonia.

753. The boracic acid forms, with ammonia, a *Borate of ammonia*, composed according to Berzelius (*Annals of Philosophy*, iii. 57,) of

37,95	Acid
30,32	Ammonia
31,73	Water

754. Boron burns in chlorine, but the chloride has not been examined, nor have its other compounds been investigated.

CHAPTER IV.

OF THE METALS, AND THEIR COMBINATIONS.

755. THE metals constitute a numerous and important class of simple substances; many of them were diligently examined by the older chemists, who have left us valuable information concerning them; many are of more recent discovery; and the existence of several others has been demonstrated within the last twenty years.

The metals are forty-two in number.

Number of metals.

		Discovered by.	Date.
1	Gold	Known since the remotest antiquity.	
2	Silver		
3	Copper		
4	Iron		
5	Mercury		
6	Tin		
7	Lead		
8	Zinc	Known to Paracelsus, who died	1541(1
9	Bismuth	Described by Agricola	1520(2
10	Antimony	" " Basil Valentine	15th cent.(3)
11	Arsenic	Brandt	1733(4
12	Cobalt		
13	Platinum	Wood, assay master, Jamaica	1741(5
14	Nickel	Cronstedt	1751(6
15	Manganese	Gahn and Schele	1774(7
16	Tungsten	M. M. Delhuyart	1781(8
17	Tellurium	Muller	1782
18	Molybdenum	Do. and Hielm	1782
19	Uranium	Klaproth	1789
20	Titanium	Gregor	1781
21	Chromium	Vauquelin	1797(9
22	Columbium	Hatchett	1802(1
23	Palladium	Wollaston	1803(1
24	Rhodium		
25	Iridium	Descostils and Tennant	1803
26	Osmium	Tennant	1803(1
27	Cerium	Hisinger and Berzelius	1804(1
28	Potassium	Sir H. Davy	1807
29	Sodium		
30	Lithium	Arfwedson	1818
31	Barium	Sir H. Davy	
32	Calcium		
33	Strontium		
34	Magnesium		
35	Silicium		
36	Alumium		
37	Yttrium		
38	Glucium		
39	Zirconium		
40	Thorinum	Berzelius	1815—17
41	Selenium		
42	Cadmium	Stromeyer	1818

756. Of these metals the first seven were known in ver
remote ages. The ancients designated them by the names

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(1) Pliny, Lib. xxxiv cap. 2 and 10. (2) Mentioned in the *Bermannus* of Agricola written ab
1530. (3) *Currus triumphalis Antimonii*. (4) *Acta Upsal* 1733 and 42. (5) *Phil Trans* V
xliv. (6) *Stockholm Trans.* (7) Bergman's *Opuscula*, Vol. ii. (8) *Memoires de Toulouse.* (
Annales de Chimie, Vol. xxv. (10) *Phil. Trans.* (11) *Phil. Trans.* (12) Gehlen's *Jour.* ii.

the planets, to which they were supposed to have some mysterious relation; and each was denoted by a particular symbol, representing both the metal and the planet.

Ancient symbols.

Gold	was the Sun, and was thus represented	☉
Silver	Moon	☽
Mercury	Mercury	☿
Copper	Venus	♀
Iron	Mars	♂
Tin	Jupiter	♃
Lead	Saturn	♄

757. The metals seldom occur in the earth in a pure, or as it is termed by mineralogists, in a *native* state; but almost always united with other substances, as in the four following classes:—

Native metals.

i. *Native Metals* are those which occur pure or alloyed, and have but a feeble attraction for oxygen; such as platinum, gold, silver, mercury and copper.

Combined with Electro-negative substances. Oxides, &c.

ii. *Metals combined with electro-negative substances* (245.) The compounds belonging to this class are chiefly *native metallic oxides;* there are also a few native *chlorides*, but no iodides have hitherto been discovered. The *fluorides*, of which there are a few, may also be regarded as belonging to this class.

—with Electro-positive substances—Sulphurets.

iii. *Metals combined with Electro-positive, or simple accidifiable, substances* (326.) This class includes the native *metallic sulphurets*, a very numerous and important series of ores, one native *carburet* only is known, that of iron. There are no native hydrurets, phosphurets, nor borurets.

—with acids.

iv. *Metals in combination with acids—Metallic salts.* Of these the most common are the native *carbonates*, *sulphates*, and *phosphates:* there are a few native *borates;* and a few species belonging also to this class in which the oxide is united to a *metallic acid:* such as the *native arseniates*, *chromates*, *tungstates*, and *molybdates*.

General characteristics.

758. The metals, as a class, are characterized by a peculiar lustre and perfect opacity: they are excellent conductors of heat, (118) and of electricity (192.)

759. They are *also* excellent reflectors, not only of light but of caloric, and hence they are the best materials for the composition of burning mirrors. From the experiments of Mr Leslie, they appear to possess this property in the following order, the highest number denoting the greatest reflecting power.

Brass	100
Silver	90
Tinfoil	85
Planished block tin	80
Steel	70
Lead	60
Tinfoil softened by mercury	50

In general the reflecting power was found by Mr Leslie, to be proportionate to the degree of polish (111, 112) and to be impaired by every thing that diminished this quality. A tin reflector for example, had its reflecting power diminished nine tenths by being rubbed with sand paper. LESLIE *on Heat*, p. 98.

760. There is the greatest difference in the specific gravity of the different metals, the heaviest and lightest solids being included in the list.

The principal metals, arranged according to their specific gravities stand as follow:

Order of specific gravities.

1	Platinum	21,00
2	Gold	19,30
3	Iridium	18,68
4	Tungsten	17,50
5	Mercury	13,50
6	Palladium	11,50
7	Lead	11,35
8	Rhodium	10,65
9	Silver	10,50
10	Bismuth	9,80
11	Uranium	9,00
12	Copper	8,90
13	Arsenic	8,35
14	Nickel	8,25
15	Cobalt	8,00
16	Iron	7,78
17	Molybdenum	7,40
18	Tin	7,30
19	Zinc	7,00
20	Manganese	6,85
21	Antimony	6,70
22	Tellurium	6,10
23	Sodium	0,972
24	Potassium	0,865*

761. The specific gravity of solids and liquids is always expressed in numbers referring to water as = 1.

Method of determining specific gravity.

Of solids.

To ascertain the specific gravity of solids we employ a delicate balance, so contrived as to admit of substances being attached to one of the scales by means of a horse-hair or a fine thread of silk. The absolute weight of the body thus suspended is then very carefully ascertained: it is next immersed in distilled water, of the temperature of 60°; and the beam being again brought to an equilibrium, we learn the weight lost by its immersion; or, in other words, we ascertain the weight of its bulk of pure water. We now divide the sum of its absolute weight by that of the weight which it lost in water, and the quotient is its *specific weight*, or gravity, compared with water of the temperature of 60°

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*For other metals, &c. see *Tables*.

Suppose a substance, weighing 360 grains, to lose 60 by immersion in water. the specific gravity of that substance will be = 6; for 360 ÷ 60 = 6.

762. For ascertaining the specific gravity of liquids, we generally employ a thin phial, fig. 29 holding 1000 grains of distilled water, at the temperature of 60°. If filled with any other liquid, and weighed, we learn its specific gravity; thus we should find that it would contain 13500 grains of mercury; 1850 grains of sulphuric acid; 1420 grains of nitric acid, &c., which numbers of course represent the specific gravities of those liquids. Of fluids. Pl. 1.

A bottle, however, holding 1000 grains is often inconveniently large, and a small and thin globular phial, with a piece of thermometer tube ground into it by way of stopper will be found more useful: such a phial should not weigh more than from 50 to 60 grains, and may contain between 4 and 500 grains of water. To use it, it should be accurately counterbalanced in a delicate pair of scales, and then filled with distilled water, and the stopper thurst in, the capillary opening in which allows a little to ooze out, and prevents the likelihood of bursting the phial; it is then to be wiped clean and dry, and again carefully weighed, by which the quantity of water it contains is ascertained; the water being poured out, it is next filled with the liquid whose specific gravity is required, taking care that it is of the same temperature as the water; we then weigh as before, and divide the weight by the former weight of water, the product gives the specific gravity required. Thus, suppose the phial to contain 425 grains of water at the temperature of 45°, it will be found to hold 5737,5 grains of pure mercury of the same temperature; and 5737,5 ÷ 425 = 13,5 the specific gravity of mercury. Or, supposing the liquid lighter than water, such as alcohol, of which we may assume the phial to contain 350,5; then 350,5 ÷ 425 = 0,824 the specific gravity of the alcohol under trial.

763. Among the metals, some are *malleable*, others *brittle*.

Malleability, or the capacity of being extended by the hammer belongs to the following metals, in the order following: Malleability.

List and order of malleable metals.

Gold
Silver
Copper
Tin
Cadmium
Platinum
Lead
Zinc
Iron
Nickel
Palladium

Potassium, sodium, and frozen mercury, are also malleable.

Malleability is one of the most useful properties of the metals. In this quality, gold takes place of all the rest. The gold leaf, which is sold in books, is so extremely thin, that less than five grains cover a surface of about 272¼ square inches; and the thickness of each leaf does not exceed $\frac{1}{282000}$th part of an inch. H. 1. 460.

764. The malleable metals are also *ductile;* that is, they admit of being drawn out into wires. They are arranged according to ductility as follows;

Of ductile metals.

Gold
Silver
Platinum
Iron
Copper
Zinc
Tin
Lead
Nickel
Palladium

765. Different metallic wires are possessed of different degrees of *tenacity*, by which is meant the power of supporting a weight without breaking. According to the experiments of Guyton Morveau, the following are the weights capable of being sustained by wires $\frac{787}{1000}$ths of a line in diameter.—*Annales de Chimie*, lxiv.:

Metals possessing tenacity, with the power of each.

	lbs. avoird. decimal parts.
A wire of Iron supports .	549.250
Copper . . .	302,278
Platinum . .	274,320
Silver . . .	187,137
Gold	150,753
Zinc	109,540
Tin	34,630
Lead	27,621

and elasticity.

766. Some of the malleable and ductile metals have, also, a high degree of elasticity. This property fits them for being applied to the mechanical purpose of springs. Steel and iron are, in this respect, superior to all other metals. Upon the properties of elasticity and hardness, appears also to depend that of *fitness for exciting sound*, for whatever renders metals harder and more elastic, increases also their sonorousness. Thus bell metal is more remarkable for those properties than either tin or copper, which are its constituents. H. 1. 462.

767. The following metals are brittle:

Brittle metals.

Antimony
Arsenic
Bismuth
Cerium
Chrome
Cobalt
Columbium
Manganese
Molybdenum
Tellurium
Tungsten
Titanium
Uranium

768. None of the metals are very *hard*, and many so soft as to yield to the nail. In the following table some of the metals are arranged in the order of their hardness:

Order of their hardness.

Tungsten
Palladium
Manganese
Iron
Nickel
Platinum
Copper
Silver
Bismuth
Gold
Zinc
Antimony
Cobalt
Tin
Arsenic
Lead.

769. The *structure or texture* of several of the metals appears to be *crystalline*. That of iron developed by the action of solvents, has been shown by Mr Daniel to be fibrous. Bismuth, and antimony have a lamellated texture; nickel presents a fracture between fibrous and foliated; and steel is granular. Several of the metals, when melted and cooled under favourable circumstances, form regular crystals. Thus bismuth, melted in a crucible, and suffered to cool becomes covered with a crust, and when this is pierced, and the fluid beneath allowed to flow out, the cavity is found studded with beautifully regular cubic crystals. Arsenic crystallizes in regular tetraedrons, and titanium in long slender filaments or prisms. H. 1. 462. Texture.

Such are the essential physical characters of the metals; they also resemble each other in many of their chemical properties, as the following general observations show:

770. *Action of Heat.*—The metals are all susceptible of fusion by heat, but the temperatures at which they liquefy are extremely various. Mercury is fluid at all common temperatures, and requires to be cooled to — 39° before it congeals. Potassium melts at 150° and sodium at 200°: arsenic at 360°; tin at 450°; lead at 600°; zinc at 700°; and antimony at 800°. Silver, gold, and copper require a bright cherry-red heat; iron, nickel, and cobalt, a white heat; manganese and palladium, an intense white heat; molybdenum, uranium, tungsten, and chrome, are only very imperfectly agglutinated at the highest temperatures of our furnaces; and titanium, cerium, osmium, iridium, rhodium, platinum, and columbium, require the intense heat produced by an inflamed current of oxygen and hydrogen, or that of Voltaic electricity. Action of heat

At higher temperatures than that required for their fusion many of the metals are volatile, and may be distilled in close vessels. Mercury, arsenic, potassium, tellurium, and zinc, are volatile at a dull red heat. Gold and silver are converted into vapour when exposed to the intense heat of the focus of a burning lens; and several of the other metals boil and evaporate under similar circumstances. It is probable that this would happen to all of them, if raised to sufficiently high temperatures.

771. *Action of Oxygen.*—When the metals are exposed at ordinary temperatures to the action of oxygen, or of common air, which produces analogous, though less powerful effects, they are very differently affected. If the gas be perfectly dry, very few of them suffer any change unless heated in it; they then lose their metallic characters, and form a very important series of compounds, the *metallic oxides*. Action of oxygen.

772. A few of the metals resist the action of heat and air so completely, that they may be kept in fusion in an open crucible for many hours without undergoing change. This is the case with gold and silver, and a few others; hence they were called *perfect* or *noble* metals: they may, however, be oxidized by Perfect or noble metals.

the Voltaic flame; or by passing a strong electric discharge through them, when drawn into very fine wire.

Metals absorb Oxygen.

773. Other metals readily absorb oxygen when exposed to a temperature approaching a red heat; as iron, mercury, nickel, *&c.*; others absorb it when in fusion, as lead, tin, antimony, *&c.*; others at lower, or even at common temperatures, as arsenic, manganese, sodium, potassium, *&c.*

Their attraction for oxygen different.

774. That the metals have very different attractive powers in regard to oxygen is also shown by the circumstance of one metal being frequently oxidized at the expense of another; thus the oxide of mercury, heated with metallic iron, produces metallic mercury and oxide of iron; potassium, heated with oxide of manganese, becomes oxidized, and metallic manganese is obtained.

Oxides decomposed by heat.

775. Some of the oxides are decomposed by mere exposure to heat, as those of gold, mercury, *&c.*; others require the joint action of heat, and some body having a high attraction for oxygen, such as charcoal. Thus when oxide of lead is heated with charcoal, carbonic acid gas is evolved, and metallic lead obtained.

Metals combine with definite quantities of oxygen.

776. Each metal has a certain definite quantity of oxygen with which it combines; and where the same metal unites in more than one proportion with oxygen, in the second, third, and other compounds, it is a multiple of that in the first, consistent with the law of definite proportions (69). Thus 100 parts of mercury combine with 4 of oxygen to produce the ***protoxide***, and with 8 to produce the ***peroxide***. Copper also forms two oxides; in the one 12,5 of oxygen are united to 100 of metal, and in the other 25.

Metallic acids.

777. Among the combinations of metals with oxygen, some are insoluble in water, or nearly so, and have neither taste nor smell; others are soluble and sour, constituting the ***metallic acids:*** others are soluble and alkaline, forming the ***fixed alkalies*** and ***alkaline earths***. They are of all colours, and frequently the same metal united to different proportions of oxygen produces compounds differing in colour: thus we have the ***black*** and ***red*** oxide of mercury, the ***white*** and the ***black*** oxide of manganese, *&c.*

Action of acids dependent on state of oxidation of metals.

778. There is a certain state of oxidation, peculiar to the different metals, in which they are most readily acted upon by the several acids. Iron and manganese, for example, at the maximum of oxidizement, are altogether insoluble in nitric acid; but readily dissolve in it, when combined with a smaller proportion of oxygen. Even when once brought into combination with that acid, the oxide, by attracting a further quantity of oxygen from the atmosphere, or from any other source, is separated in the state of an insoluble precipitate, which, however, does not consist of pure oxide, but of the oxide, with a certain proportion of acid. This explains the change, which is produced in solutions of iron, by keeping them exposed to air. The oxides of iron and manganese, saturated with oxygen, are

soluble, however, in the less oxygenated acids; for example, in the sulphurous or nitrous, which first deprive the oxide of part of its oxgen, and then dissolve the less saturated oxide. H. 1. 472.

Action of chlorine.

779. *Action of Chlorine.*—All the metals appear susceptible of combining with chlorine, and of producing a class of compounds which may be termed *metallic chlorides.*

There are a few of the metals which resist the action of chlorine at common temperatures, but when heated they all combine with it; some slowly, others rapidly and with intense ignition. Copper leaf, powdered antimony, arsenic, *&c.*, burn when thrown into the gas: mercury and iron inflame when gently heated in it; silver, gold, and platinum quietly absorb it.

780. The attraction of chlorine for metals is greater than that of oxygen; consequently, when a metallic oxide is heated in chlorine, oxygen is evolved, and a chloride formed. The insoluble chlorides are also formed by adding solution of chlorine, or of muriatic acid, to the soluble metallic salts. Thus chloride of silver which is insoluble, is thrown down from the soluble nitrate of silver by solution of chlorine, of muriatic acid, and of common salt.

Properties of the Chlorides various.

781. The physical and chemical properties of the chlorides are extremely various. They are nearly of all colours. Some are unchanged by heat; others undergo decomposition. Some are soluble, others insoluble, in water. Several of them decompose water, giving rise to the formation of muriatic acid, and an oxide; or in some cases to a muriate. The same metal often forms more than one compound with chlorine, and these compounds are designated as the oxides. Thus we have the *protochloride* and *perchloride* of mercury, *&c.*

Decompose muriatic acid.

782. Many of the metals decompose muriatic acid in which case hydrogen is evolved, and a metallic chloride produced: and when metallic oxides are heated in muriatic acid, they generally give rise to the formation of a chloride and water.

Action of chloric acid.

783. *Action of Chloric Acid.*—The compounds of the metallic oxides with chloric acid are decomposed by heat with the copious evolution of oxygen, and a chloride generally remains: some of these salts have been long known, others only recently investigated. The *oxychlorates* have been scarcely examined.

Action of Iodine.

784. *Action of Iodine.*—Iodine aided by heat acts upon many of the metals, and produces *metallic iodides.* Some of these are soluble in water without decomposition; others decompose water and produce *hydriodates;* others are insoluble. The insoluble iodides may generally be formed by adding a solution of iodine or of hydriodic acid to the soluble metallic salts.

Iodine often combines in more than one proportion with metals, forming a *protiodide* and a *periodide.*

Action of Iodic acid.

785. *Action of Iodic Acid.*—The compounds of this acid with the metallic oxides have been but little examined: they are decomposed by heat, sometimes with the evolution of oxygen only; at others, iodine is also given off.

Action of hydrogen.

786. *Action of Hydrogen.*—Hydrogen forms permanent compounds with two of the metals only, namely, arsenic and tellurium. It appears to combine with each in two proportions, forming two solid compounds, the ***hydrurets*** or ***hydrogurets*** of arsenic and tellurium; and two gaseous compounds, ***arsenuretted*** and *telluretted hydrogen*. At high temperatures it dissolves potassium, forming ***potassiuretted hydrogen gas.***

There are many of the metallic oxides, and a few of the chlorides, which are decomposed by hydrogen: the oxides are reduced with the formation of water, and the chlorides with the production of muriatic acid.

Action of water.

787. *Action of Water.*—Those metals which are speedily acted upon by common air and oxygen, are also generally susceptible of decomposing water; some of them rapidly, others slowly. There are some metals which are not acted upon by air deprived of moisture, nor by water deprived of air; but moist air, or water containing air, effect their oxidizement: this appears to be the case with iron.—Dr MARSHALL HALL. *Quarterly Journal*, vii. 55.

Hydrated oxides.

Water combines with some of the metallic oxides, and produces *hydrated oxides*, or ***metallic hydrates***. In these the relative proportion of water is definite. Some are easily decomposed by heat, as hydrate of copper; others retain water even when heated to redness, as hydrate of potassa.

Action of nitric acid.

788. *Action of Nitric Acid.*—As no metal is soluble in an acid except in the state of oxide, and as the greater number of metals are capable of decomposing nitric acid, and of resolving it into some of the other nitric compounds, nitric acid is a very generally acting solvent of these bodies. It dissolves all the metallic oxides and produces a numerous class of ***nitrates***, which if prepared with heat and with excess of acid, generally contain the metal at its maximum of oxidizement. The nitrates are all decomposed by a red heat; they give off oxygen, either separate, or combined, and the metallic oxide remains. They are also decomposed when heated with sulphur, phosphorus, or charcoal; and sulphurous, phosphoric, and carbonic acids are formed; the phosphoric, being a fixed acid, remains united to the metallic oxide; while the sulphurous and carbonic acids are usually expelled. The nitrates are decomposed by sulphuric acid, nitric acid is evolved, and *sulphates* are formed.

Porportion of oxygen in neutral nitrates.

789. In the neutral nitrates the proportion of oxygen in the acid is to that in the base as 5 to 1. Thus in the nitrate of potassa 48 parts of potassa, containing 8 of oxygen, are combined with 54 of nitric acid, containing 40 of oxygen; and in the pernitrate of copper, 80 parts of peroxide of copper containing 16 of oxygen, are combined with 108 of nitric acid, containing 84 of oxygen.

Action of ammonia.

790. *Action of Ammonia.*—At high temperatures some of the metals are capable of decomposing ammonia. Liquid ammonia dissolves several of the metallic oxides, and with some

of them forms crystallizable compounds. The compounds of ammonia with the oxides of gold, silver, and platinum, detonate when heated, and the oxide and the ammonia are both decomposed.

Action of sulphur.

791. *Action of Sulphur.*—All the metals appear capable of forming *sulphurets.* These are in some cases formed by heating the metal with sulphur; in others, by decomposing the sulphates; and in others, by the action of sulphuretted hydrogen. The sulphurets are in general brittle; some have a metallic lustre; others are without lustre. Some are soluble, others insoluble in water. When the same metal forms two sulphurets, the sulphur in those containing the largest proportion is an exact simple multiple of the sulphur in those containing the smallest proportion. When the metallic sulphurets are heated, some undergo no change, as those of sodium and potassium; others sublime unaltered, as sulphuret of mercury; others lose a portion of their sulphur, and if air be admitted, sulphurous acid escapes and the metal passes into the state of oxide, as sulphuret of lead; others again are entirely decomposed, the metal being completely reduced; this happens on heating sulphuret of platinum or of gold. It is doubtful whether any definite compounds of sulphur with the metallic oxides exist.

Hyposulphites.

792. *Hyposulphurous acid* combines with the metallic oxides and produces a class of salts termed *hyposulphites.* Several of these have been examined by Mr Herschel (*Edinburgh Philosophical Journal,* i.) In some of their characters they resemble the sulphites: they are easily soluble; of a bitter or sweet taste; and decomposed by a heat below redness, and by almost all other acids. Their solutions readily dissolve chloride of silver.

Sulphites.

793. *Sulphurous acid* combines with many of the metallic oxides, producing *sulphites;* in some instances oxygen is transferred from the oxide to the acid, and sulphates result.

The *sulphites* are soluble in water, and have a sulphurous taste and smell. Exposed to moist air, they absorb oxygen, and pass into the state of sulphates. They are decomposed by sulphuric acid, which expels sulphurous acid, and the salts are converted into sulphates. When perfectly pure they are not affected by solution of baryta.

Hyposulphates.

794. *Hyposulphuric acid* forms with the metallic oxides a class of hyposulphates which have been very imperfectly examined. They do not afford precipitates with solution of baryta.

Sulphates.

795. *Sulphuric acid,* in its concentrated state, is acted upon by a few of the metals only; when diluted, some of them are oxidized at the expense of the water, hydrogen is evolved, and the metallic oxide combines with the acid, producing a *sulphate.* In these cases the hydrogen evolved is the indicator of the quantity of oxygen transferred to the metal; every volume of hydrogen is the equivalent of half a volume of oxygen, and accordingly the production of 100 cubic inches of hydrogen,

indicates the transfer of 50 of oxygen, or by weight of about 17 grains. As different metals unite to different weights of oxygen, they will obviously evolve different quantities of hydrogen. Thus, if one metal, to become soluble in sulphuric acid, require to be united with 15, and another with 30 per cent. of oxygen, the latter will evolve twice the volume of hydrogen, compared with the former.

As the evolution of hydrogen, during the solution of a metal in dilute sulphuric acid, is referable to its oxidizement, no hydrogen will be evolved by the action of the acid upon an oxide, but it will be merely dissolved.

The sulphates are an important class of salts. The greater number of them are soluble in water, and the solutions are rendered turbid by solutions of baryta. They are all decomposed at a red heat by charcoal, and most of them are thus converted into sulphurets; carbonic acid, and carbonic oxide, being at the same time evolved.

In the neutral sulphates the proportion of oxygen in the acid is to that in the base as 3 to 1, Thus sulphate of soda is composed of 32 soda containing 8 of oxygen, combined with 40 of sulphuric acid containing 24 of oxygen.

Sulphuretted hydrogen.

796. *Action of Sulphuretted Hydrogen.*—It seems doubtful whether any of the metals combine with sulphuretted hydrogen. It unites with several of their oxides, and forms *hydrosulphuretted oxides.* Many of these compounds are insoluble, and may be formed by adding a solution of sulphuretted hydrogen, or of hydrosulphuret of ammonia, to solutions of the respective metallic salts. Sometimes, however, a decomposition is effected in these cases, both of the sulphuretted hydrogen and of the oxide, and a metallic sulphuret is formed, the hydrogen combining with the oxygen of the oxide to form water, and the sulphur uniting to the metal. In a few cases the metallic oxide is reduced.—For the effect of sulphuretted hydrogen and of hydrosulphuret of ammonia upon solutions of several of the metals, as far as colour of the precipitate is concerned, see *Tables.*

Action of phosphorus.

797. *Action of Phosphorus.*—Phosphorus combines with the greater number of the metals, forming a series of *metallic phosphurets.* There are two methods of forming them; either by heating a mixture of phosphorus and the metal, or projecting phosphorus upon the metal previously heated to redness; or by heating a mixture of the metal or its oxide, with phosphoric acid and charcoal. These phosphurets have a metallic lustre; if they contain a difficultly fusible metal they are more fusible than the metal they contain; if an easily fusible metal, less so. They are mostly crystallizable, and totally or partially decomposable at a high temperature. The greater number of the phosphurets have only been examined by Pelletier. —*Annales de Chimie,* Tom. i. *et* xiii. and *Mémoires et observations de Chimie.*

Phosphates.

798. The *metallic phosphates* may be formed either by dissolving the oxides in phosphoric acid, or by adding a solution of phosphoric acid, or of an alkaline phosphate, to solutions of those metals which form insoluble or difficultly soluble phosphates. The greater number of the phosphates are decomposed by ignition with charcoal; and those containing volatile oxides are volatilized at high temperatures.

In the neutral phosphates the quantity of oxygen in the acid is to that in the base as 2 to 1. Thus phosphate of soda consists of 32 soda containing 8 oxygen, and 28 phosphoric acid containing 16 of oxygen.

Exp.

799. When phosphorus is introduced into the solutions of those metals which have but a feeble attraction for oxygen, it reduces them to the metallic state. Thus gold, silver, and platinum are thrown down by immersing a stick of phosphorus into their respective solutions.

Action of carbon.

800. *Action of Carbon.*—Carbon unites to very few of the metals, and of the metallic carburets, one only is of importance namely carburet of iron, or *steel.*

Carbonates.

801. *Carbonic acid* unites with the greater number of the metallic oxides and forms *Carbonates,* of which the distinctive characters have already been noticed; many of them are of difficult solubility, and may be formed by adding an alkaline carbonate to the metallic solution. Of the carbonates some are entirely, and others only partially decomposed at a red heat. Carbonate of magnesia, for instance, loses the whole of its carbonic acid at a red heat; carbonate of potassa retains it; and bi-carbonate of potassa loses one-half and passes into the state of carbonate.

Action of Boron.

802. *The action of Boron* upon the metals has not been investigated, though it appears from the experiments of Descotils, (*Recherches Physico-chymiques de* M. M. GAY-LUSSAC et THENARD) to be capable of uniting to platinum and iron. These compounds may be called *borurets.* The metallic *borates* are numerous but mostly unimportant. Many of them are insoluble and easily formed by adding solution of boracic acid, or a soluble borate to the metallic solution.

Action of metals upon each other.

803. *Action of Metals upon each other.*—The metals may for the most part be combined with each other, forming a very important class of compounds, the *metallic alloys.*

Alloys.

In the new nomenclature, the word ALLOY is retained as a general term for all combinations of metals with each other; and the specific name is derived from that of the metal, which prevails in the compound. Thus in the *alloy of gold with silver,* the gold is to be understood as being in greatest proportion; in the *alloy of silver with gold,* the silver is the principle ingredient.

Amalgams.

804. The compounds of mercury with other metals, at a very early period of chemistry, were called AMALGAMS, and as the name does not lead to any erroneous notions, it may still be retained to denote this sort of alloy. H. 1. 491.

Process for forming alloys.

805. Various processes are adopted in the formation of alloys depending upon the nature of the metals. Many are prepared by simply fusing the two metals in a covered crucible; but if there be a considerable difference in the specific gravity of the metals, the heavier will often subside, and the lower part of the bar or ingot, will differ in composition from the upper; this may be prevented by agitating the alloy till it solidifies. Mr Hatchett found that when an alloy of gold and copper was cast into bars, the moulds being placed perpendicularly, the upper part of the bar contained more copper than the lower.—*Phil. Trans.* 1803.

When one of the metals is very volatile, it should generally be added to the other after its fusion; and if both metals be volatile, they may be sometimes united by distilling them together.

It has been a question whether alloys are to be considered as compounds, or as mere mixtures; but their properties leave little doubt of their being real compounds, and in some cases they are found to unite in definite proportions only; and it is probable that all the alloys contain a definite compound of the two metals.

806. The principal characters of the alloys are the following:

Characters of alloys.

i. We observe a change in the ductility, malleability, hardness, and colour. Malleability and ductility, are usually impaired, and often in a remarkable degree: thus gold and lead, and gold and tin, form a brittle alloy. The alloy of copper and gold is harder than either of its component parts; and a minute quantity of arsenic added to copper, renders it white.

ii. The specific gravity of an alloy is rarely the mean of its component parts; in some cases an increase, in others a diminution of density having taken place.

Fusibility greater than that of their components;

iii. The fusibility of an alloy is generally greater than that of its components. Thus platinum, which is infusible in our common furnaces, forms, when combined with arsenic, a very fusible alloy; and an alloy of certain proportions of lead, tin, and bismuth is fusible at 212°, a temperature several degrees below the melting point of its most fusible constituent.

More oxidizable.

iv. Alloys are generally more oxidizable than their constituents taken singly; a property which is, perhaps, partly referable to the formation of an electrical combination. Where an alloy consists of two metals, the one easily and the other difficultly oxidizable, it may be decomposed by exposing it to the action of heat and air, the former metal being converted into an oxide; its last portions, however, are often not easily separated, being protected by combination with the least oxidable metal. An alloy of three parts of lead and one of tin is infinitely more oxidizable than either of its components, and easily burns at a dull red heat.

Action of acids on alloys.

v. The action of acids on alloys may generally be anticipated by a knowledge of their effects upon the constituent metals;

but if a soluble metal be alloyed with an insoluble one, the former is often protected by the latter from the action of an acid. Thus, silver alloyed with a large quantity of gold, resists the action of nitric acid in consequence of the insolubility of the latter metal in that acid; and, in order to render it soluble, it is requisite that it should be made to form about a fourth part of the alloy, in which case the nitric acid extracts it, and leaves the gold in an insoluble film or powder.*

807. Various classifications of the metals have been adopted by chemical authors; some dependent upon their physical, others upon their chemical properties. The former can scarcely be considered as adapted to chemical inquiry, and the latter involve numerous difficulties in consequence of the gradual transition of metals of one class into those of another. We may consider the metals in the order in which they are set down in the following Table, and which is nearly that of their respective attractions for oxygen.

Metals in the order of their attractions for oxygen.

1 Potassium
2 Sodium
3 Lithium
4 Calcium
5 Barium
6 Strontium
7 Magnesium

8 Manganese
9 Iron
10 Zinc
11 Tin
12 Cadmium

13 Copper
14 Lead
15 Antimony
16 Bismuth
17 Cobalt
18 Uranium
19 Titanium
20 Cerium
21 Tellurium
22 Selenium

23 Arsenic
24 Molybdenum
25 Chromium
26 Tungsten
27 Columbium

28 Nickel
29 Mercury
30 Osmium
31 Iridium
32 Rhodium
33 Palladium
34 Silver
35 Gold
36 Platinum

37 Silicium
38 Alumium
39 Zirconium
40 Glucium
41 Yttrium
42 Thorinum

Of these metals the first seven produce alkaline oxides which are very difficult of reduction; and they rapidly decompose water at all temperatures, a character which announces their powerful attraction for oxygen; the next five decompose water when their temperature is raised to redness: the ten following do not decompose water at a red heat; nor do the next five, which produce acids by uniting to oxygen. The oxides of these twenty-seven metals are not reducible by heat alone, though some of them, when heated, give out a portion of oxygen. The nine metals which next follow, osmium excepted, have a comparatively feeble attraction for oxygen; and when their oxides are heated, they are reduced to the metallic state. The last six metals are placed in the list from analogy; they are only known in the state of oxides, which have not hitherto been reduced.

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* This constitutes the process called *Quartation*.

SECTION I. *Potassium.*

Discovery.

808. This metal was discovered in 1807 by Sir H. Davy (*Philos. Trans.* 1808.) He obtained it by submitting caustic potassa, or potash, to the action of Voltaic electricity: the metal was slowly evolved at the positive pole.

Its existence how inferred.

809. To this discovery and others of a similar kind Sir H. Davy was led by a train of inductive reasoning, which is not surpassed by any investigation in the history of the physical sciences. From the facts which had become known respecting the powers of electrical decomposition, it appeared to be a natural inference, that the same powers applied in a state of the highest intensity might disunite the elements of some bodies, which had resisted all other instruments of analysis. If potassa, for example were an oxide, composed of oxygen united to an inflammable base, it seemed probable that when subjected to the action of opposite electricities, the oxygen would be attracted by the positive wire and repelled by the negative. At the same time, the reverse process might be expected to take place with respect to the combustible base, the appearance of which might be looked for at the negative pole.

Davy's experiments.

810. In his first experiments, suggested by these views, Sir H. Davy failed to effect the decomposition of potash, owing to his employing the alkali in a state of aqueous solution, and to the consequent expenditure of the electrical energy in the mere decomposition of water. In his next trials, the alkali was liquefied by heat in a platinum dish, the outer surface of which, immediately under the alkali, was connected with the zinc or positive end of a battery consisting of 100 pairs of plates, each six inches square. In this state the potash was touched with a platinum wire proceeding from the copper or negative end of the battery; when instantly a most intense light was exhibited at the negative wire, and a column of flame arose from the point of contact, evidently owing to the developement of combustible matter. The results of the experiments could not, however, be collected, but were consumed immediately on being formed.

Method of obtaining potassium by electricity.

811. The chief difficulty in subjecting potassa to electrical action is, that, in a perfectly dry state, it is a complete non-conductor of electricity. When rendered, however, in the least degree moist by breathing on it, it readily undergoes fusion and

decomposition, by the application of strong electrical powers. For this purpose, a piece of potash. weighing from 60 to 70 grains, may be placed on a small insulated plate of platinum, and may be connected, in the way already described, with the opposite end of a powerful electrical battery, containing not less than 100 pairs of six inch plates. On establishing the connexion, the potash will fuse at both places, where it is in contact with the platinum. A violent effervescence will be seen at the upper surface, arising, as Sir H. Davy has ascertained, from the escape of oxygen gas. At the lower or negative surface, no gas will be liberated; but small bubbles will appear, having a high metallic lustre, and being precisely similar in visible characters to quicksilver. Some of these globules burn with an explosion and bright flame; while others are merely tarnished, and are protected from farther change by a white film, which forms on their surface.

Produced in vacuo.

This production of metallic globules is entirely independent of the action of the atmosphere; for Sir H. Davy finds, that they may be produced *in vacuo*.

How preserved.

812 To preserve this new substance, it is necessary to immerse it immediately in pure naptha, a fluid which will be described in a subsequent part of the work. If exposed to the atmosphere, it is rapidly converted back again into the state of pure potassa. To prevent its oxidation still more effectually, Mr Pepys has proposed to produce it under naptha; and has contrived an ingenious apparatus for this purpose, which is described in the 31st volume of the *Philosophical Magazine*, page 241.

813. Nothing can be more satisfactory than the evidence furnished by these experiments, of the nature of one of the fixed alkalies. By the powerful agency of opposite electricities, it is resolved into oxygen and a peculiar base. This base like other combustible bodies, is repelled by positively electrified surfaces, and attracted by negative ones; and hence its own natural state of electricity must necessarily be positive. Again, by uniting with oxygen, it is once more changed into alkali, either slowly at ordinary temperatures; or with heat and light, at high temperatures. We have the evidence, therefore, both of analysis and synthesis, that potassa is a compound of oxygen with a peculiar inflammable basis.

Reasons for considering it a metal.

814. In assigning to this newly discovered substance a fit place among the objects of chemistry, Sir H. Davy was induced to class it among the metals, because it agrees with them in opacity, lustre, malleability, conducting powers as to heat and electricity, and in its qualities of chemical combination. The only property which can be urged against this arrangement, is its extreme levity, which even exceeds that of water. But when we compare the differences which exist among the metals themselves, this will scarcely be considered as a valid objection. Tellurium, for example, which no chemist hesitates to consider

as a metal, is only about six times heavier than the base of potassa, while it is four times lighter than platinum; thus forming a sort of link between the old metals and the bases of the alkalies.

815. In giving names, therefore, to the alkaline bases, Sir H. Davy has adopted that termination, which, by common consent, has been applied to other newly discovered metals, and which, though originally Latin is now naturalized in our language. The base of potassa he has called POTASSIUM, and the base of soda, SODIUM; and these names have met with universal acceptation among chemical philosophers.

Other processes for obtaining potassium.

816. *Process for preparing Potassium.*—It is not, however, by electrical means only that the decomposition of potassa has been accomplished. Soon after Sir H. Davy's discoveries were known at Paris, Messrs Gay-Lussac, and Thenard* succeeded in their attempts to decompose both the fixed alkalies, without the aid of a Voltaic apparatus, merely by the intervention of chemical affinities. Their process, though it affords the alkaline bases of less purity, yields them in much larger quantity, than the electrical analysis, *viz.* to the amount of nearly 400 grains by one operation. It consists in bringing the alkalies into contact with intensely heated iron, which, at this temperature, attracts oxygen more strongly than the alkaline base retains it.

Apparatus for obtaining potassium.

817. The apparatus used for obtaining potassium, has a general resemblance to that which is employed for decomposing water by means of iron. It consists of a gun-barrel curved as in fig. 120, which is copied from Thenard's *Traité de Chimie.* At one end the barrel is drawn out to rather a smaller diameter; and, before being used, it is to be covered between *b* and *f*, with a lute of infusible clay,—(the lute may consist of five parts sand and one potters clay—) which should be suffered to dry thoroughly. Into the barrel between *f* and *b*, clean iron turnings are to be introduced, and between *a* and *b* pieces of solid hydrate of potassa. A tube of safety is to be luted to the end *a*, and is to be immersed in mercury in the glass vessel *m*. To the smaller end of the barrel, a short piece of copper tube, *g*, is accurately ground, and to this last a small copper receiver, *h*, destined to collect the potassium, is fitted by grinding. To the other end of *h*, a tube of safety, *i*, is to be luted, and made to dip into mercury contained in the vessel *l*, but to a less depth than the safety tube *m*.

A strong heat, is now to be raised in the furnace, and, while this is doing, the part of the barrel containing the potassa, as well as the end *f*, and the attached copper tube and receiver, should be kept cool by wet cloths. If gas now issues abundantly through the safety tube *i*, the junctures may be concluded to be tight. When the barrel has become white hot, the potassa may be melted by burning charcoal contained in a moveable cage *k*.

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* *Annales de Chimie*, lxv. 325; or *Memoirs d'Arcueil*, ii. 299.

It will then flow upon the intensely ignited iron turnings, and a large quantity of hydrogen gas, holding some potassium in solution, will issue through the safety tube, *i*. The cage may now be removed for a short time; and, when the production of gas slackens, it may be restored to its place. These operations may be repeated alternately till no more gas is evolved; after which the heat in the furnace should be made as intense as possible, in order to drive off some of the potassium which strongly adheres to the iron turnings. If the escape of the gas through *i* should at any time cease during the operation, and take place through *m*, this will probably be owing to a lodgment of potassium at the end *f*, of the barrel, from which it may be melted into the copper receiver, by holding a little red-hot charcoal under the part where it has condensed. The principle difficulty in the process of decomposing potassa, is to excite sufficient heat without melting the gun-barrel; and to this object the attention of the operator must be carefully directed, throughout the whole manipulation.

At the close of the operation, as soon as the vessels *g* and *h* are sufficiently cool, they are to be removed, then filled with naptha, emptied again, and quickly stopped with corks. As a portion of potassium generally remains in the portion *f*, the barrel should also be plugged by an iron stopper provided for the purpose. When sufficiently cold it may be removed from the furnace, and a little naptha passed through it. The potassium must be detached in as large pieces as possible from the barrel, and from the copper receiver, and be kept under rectified naptha in a well-stopped phial.

818. When the iron turnings are very clean, the potash very dry and pure, and the whole apparatus free from foreign matters, the metal produced differs very little from that obtained by a Voltaic battery. Its lustre, ductility, and malleability are similar. Its point of fusion and specific gravity, however, are a little higher; for it requires nearly 130° Fahr. to render it perfectly fluid, and is to water as 796 to 1000 at 60° Fahrenheit. This Sir H. Davy ascribes to contamination with a minute proportion of iron. The affinities, indeed, by which the decomposition is produced, he supposes to be those of iron for oxygen, of iron for potassium, and of potassium for hydrogen. H. 1. 407.

Mr Tennant's apparatus by which we can obtain potassium with the heat of a common forge, fig. 121, consists of a gun barrel *a*, eighteen inches long, closed at one end, and whose thickest part is widened by means of a hammer; it is coated externally with a lute similar to that mentioned in the preceding apparatus; the mixture of potash and cuttings of iron proper to furnish the potassium is introduced, and the tube is fixed with a certain inclination in a reverberatory furnace or forge *f*; in the upper part of the barrel is inserted a narrower tube *t*, seven or eight inches long, having a small hole at its Mr Tennant's apparatus.

lower end, in which the vaporized potassium ought to pass: this tube should not be entirely inserted in the former; about an inch should extend beyond it, in order to remove it with more ease; at its upper end an empty tube *v*, is fixed and closed with a cork, through which passes a bent glass tube *r*, in which a little mercury is put. The part of the tube *c*, *d*, which is out of the furnace, should be kept in wet linen or brown paper, to facilitate the condensation of the metal. Things being so disposed, a strong heat is applied about an hour, and the potassium is obtained in the tube *t*.

819. Charcoal, it has been ascertained by Curaudau,* may be employed also, for the decomposition of the alkalies. To ensure success in the process, great attention, it appears, is necessary to the manipulations, which are fully described in the memoir of the inventor. The fact sufficiently explains an observation of Professor Woodhouse.† A mixture of half a pound of soot and two ounces of pearlash was exposed, for two hours, in a covered crucible to an intense heat. When the mixture became cold it was emptied upon a plate, and a small quantity of water poured upon it, when it immediately took fire. This could only be owing to the conversion of part of the potassa into potassium. H. 1. 503.

Properties.

820. Potassium is a white metal of great lustre. It exists in small globules, which possess the metallic lustre, opacity, and general appearance of mercury; so that when a globule of mercury is placed near one of potassium the eye can discover no difference between them. It instantly tarnishes by exposure to air. It is ductile, and of the consistency of soft wax.

Its specific gravity is 0,865. At 150° it enters into perfect fusion; and at a bright red heat rises in vapour. At 32° it is a hard and brittle solid. If heated in air it burns with a brilliant white flame. It is an excellent conductor of electricity and of heat.

Combination with oxygen.

Exp.

821. *Potassium and Oxygen.*—When potassium is thrown into water, or upon a piece of ice, it instantly takes fire; hydrogen gas is evolved, and *oxide of potassium, or potassa*, is found dissolved in the water.—The quantity of hydrogen evolved in this experiment becomes the indicator of the proportion of oxygen which has been transferred to the metal; 100 parts of potassium are thus found to absorb 20 of oxygen; and if this be considered a protoxide, then $20 : 100 :: 8 : 40$,—so that 40 will be the number representing potassium, and 40 P. $+ 8$ O. $= 48$ will represent dry oxide of potassium. (B)—When water is made to act on the base of potassa, atmospheric air being excluded, there is much heat and noise, but no luminous appearance, and the gas evolved is pure hydrogen. Each grain of potassium, by acting on water, detaches about 1,06 cubic inches of hydrogen gas. H.

822. The production of alkali, by the action of water on potassium, is most satisfactorily shown, by dropping a globule

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* *Nicholson's Journal*, xxiv. 37.

† *Nicholson's Journal*, xxi. 290.

of the metal upon moistened paper, which has been tinged with turmeric. At the moment when the globule comes into contact with the paper, it burns, and moves rapidly, as if in search of moisture, leaving behind it a deep reddish-brown trace, and acting upon the paper exactly like dry caustic potassa. So strong, indeed, is the affinity of potassium for oxygen, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when carefully purified, and disengages from both these fluids, hydrogen gas. H. 1. 505. Exp.

823. Potassa, in the state it is usually met with in laboratories, contains a considerable portion of water, from which it may be freed by the action of iron at high temperatures, and there always remains in the barrel, after the above experiment, a large portion of *dry potassa.* It is a hard grey substance, which, by water, is slowly converted into the *hydrated oxide*, or caustic potash, which may be obtained by evaporation. This substance, after exposure to a red heat, is white and very soluble in water; it may be considered as a compound of 1 proportional of protoxide of potassium = 48 + 1 proportional of water 9, and its number = 57. Potassa.

824. *Peroxide of Potassium.*—If the metal be heated in considerable excess of oxygen, it burns with intense heat and light, and an orange-coloured substance is obtained, which consists of 40 potassium + 24 oxygen = 64. This peroxide of potassium, when put into water, effervesces, oxygen is given off and a solution of the hydrated protoxide is obtained. Peroxide of potassium is also formed by passing oxygen over potassa heated to redness. Peroxide.

825. The *hydrated protoxide* or *caustic potash,* is procured in our laboratories by decomposing its carbonate by lime. The best process consists in boiling in a clean iron vessel, carbonate of potassa, (obtained by calcining tartar) with half its weight of pure quick-lime, in water. The ley is strained through clean linen, concentrated by evaporation, again strained, and set by in a well-stopped bottle till it admits of being decanted clear from the sediment. The clear solution is to be evaporated to dryness. It is often cast into sticks for the use of surgeons, who employ it as a caustic, and in this state it generally contains some peroxide, and therefore evolves oxygen when dissolved in water. It is the *potassa fusa* of the *London Pharmacopœia.* It may be further purified by the action of alcohol, which dissolves the pure hydrate and leaves earthy and other impurities; the alcohol is then driven off by heat. In this case the alcohol is always in some measure acted upon by the potassa, and a portion of carbonaceous matter deposited, so that it should be allowed to remain as short a time as possible combined with the alkali. Having obtained the dry caustic alkali by lime, it may be boiled in a silver basin with highly rectified alcohol for a few minutes, and then set by in a stopped phial; when the impurities are deposited, the alcoholic solution may be poured Mode of procuring caustic potassa.

off and rapidly evaporated to dryness in a silver basin as before: the heat may then be raised so as to fuse the potassa, which, on cooling, should be broken up and preserved in well-closed phials.[*]

Characters.

Hydrate of Potassa thus purified is white, very acrid and corrosive, and at a bright red heat evaporates in the form of white acrid smoke. It quickly absorbs moisture and carbonic acid from the air, and at 60° one part of water dissolves two. It may be crystallized in octoëdrons. It is highly alkaline, and being exclusively procured from vegetables was formerly called *vegetable alkali.* When touched with moist fingers it has a soapy feel, in consequence of its action upon the cuticle. In the fused state it produces heat when dissolved in water; but in its crystallized state it excites considerable cold, especially when mixed with snow. At a natural temperature of 30°, M. Lowitz found that equal weights of crystallized potassa and snow depressed the thermometer 45°.—*Annales de Chimie,* xxii.

Chloride.

826. *Chlorine and Potassium* act very energetically upon each other, and produce the white compound which has been called *muriate of potash,* but which is a true *chloride of potassium.* According to Sir H. Davy it is constituted of 75 potassium + 67 chlorine; or of 1 atom potassium = 40 + 1 atom of chlorine = 36 and its equivalent number is 76.[†]

When potassium is heated in gaseous muriatic acid, this compound is formed, and hydrogen is evolved. It dissolves without decomposition in three parts of water at 60°. It crystallizes in cubes; its taste is saline and bitter. In old pharmacy it was called *salt of Sylvius;* also, *regenerated sea-salt.*

Chlorate,

827. *Chlorate of Potassa* is formed by passing chlorine through a solution of potassa. Chloride of potassium is one of the results, the other is a salt in brilliant rhomboidal tables (formerly called oxymuriate of potash) the chlorate.

how obtained.

This salt is prepared, upon the large scale, by charging one or two Woulfe's bottles with solution of carbonate of potassa, and passing chlorine slowly through it:[‡] the gas is absorbed,

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[*] Mr Donovan has proposed the following as a more easy method of obtaining pure potassa. The crystallized bi-carbonate of potash of the shops is to be purified by dissolving it in water at the temperature of 100.° The saturated solution must be filtered and poured into a flat dish, and placed before the fire; in a few hours a crop of crystals of the pure bi-carbonate will be obtained. They may then be rinsed with a very small quantity of water, and dried on blotting paper. The crystals are now to be dissolved in water, and boiled with their own weight of hydrate of lime for 15 minutes, the liquid is then to be filtered and we have at once a solution of pure potash, which may be evaporated as above. See *Boston Jour. of Philos.* iii. 96.

[†] Considered as a muriate of potassa (in which state this salt must always exist when in watery solution,) it may be regarded as constituted of an atom of muriatic acid 37, and an atom of potassa, 48, and its representative number is 85. Under this view it is constituted of

Acid	36,57
Potassa	63,43
	100.

H. 1. 509.

[‡] The tube, which is immersed in the alkaline solution, should be at least half an inch in diameter, to prevent its being choaked up by crystals that may form.

and the liquor effervesces chiefly from the escape of carbonic acid; when this has ceased, the liquor may be put aside in a cold dark place for about 24 hours, when it will be found to have deposited a considerable portion of the crystallized chlorate which may be taken out, drained, and purified by solution in hot water, which, during cooling again, deposits the salt in white crystalline scales. The liquor is generally of a pinkish hue, from the presence of manganese.

828. When obtained by the absorption of chlorine by solution of potassa, the changes which take place admit of being explained as follows. Part of the chlorine may be employed in decomposing the water of the alkaline solution, forming, with its hydrogen, common muriatic acid, while another portion of chlorine unites with the oxygen thus set at liberty; or the change may consist in the decomposition of potassa, the oxygen of one portion of which may be transferred to another portion, while the chlorine is partly expanded in decomposing water and forming muriate of potassa, and partly in forming a triple compound of chlorine, oxygen, and peroxide of potassium. In this view chlorate of potassa is constituted of 1 atom of potassium weighing 40, 1 atom of chlorine = 36, and 6 atoms of oxygen = 48; and its equivalent number is the sum of these, viz. 124. Theory of the process.

829. The taste of this salt is cooling and austere. When triturated it appears phosphorescent. When exposed to a dull red heat it decrepitates, fuses, and gives out oxygen, and chloride of potassium remains. It is soluble in 18 parts of cold and 2,5 of boiling water. It acts very energetically upon many inflammables. Properties.

Rub two grains into powder in a mortar, and add one grain of sulphur. Mix them very accurately, by gentle triture, and then, having collected the mixture to one part of the mortar, press the pestle down upon it suddenly, and forcibly. A loud detonation will ensue.—Or, if the mixed ingredients be wrapped in some strong paper, and then struck with a hammer, a still louder report will be produced. Exp.

Mix five grains of the salt with half the quantity of powdered charcoal in a similar manner. On triturating the mixture strongly, it will inflame, especially with the addition of a grain or two of sulphur, but not with much noise. Exp.

830. When sulphuric acid is poured upon mixtures of this salt and combustibles, instant ignition ensues in consequence of the evolution of oxide of chlorine; and when sulphuric or nitric acids are poured upon similar mixtures under water by means of a long funnel, inflammation also ensues. Action of sulphuric acid.

Mix a small quantity of sugar with half its weight of the salt, and on the mixture pour a little sulphuric acid.* A sudden Exp.

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* A mixture of this kind is the basis of the matches, now generally used for the purpose of procuring instantaneous light. The bottle into which they are dipped, contains concentrated sulphuric acid which is prevented from escaping by a quantity of finely spun glass or the fibres of amianthus.

and vehement inflammation will be produced. This experiment, as well as the following requires caution.

Exp.

To one grain of the powdered salt, in a mortar, add about half a grain of phosphorus. The phosphorus will detonate, on the gentlest triture, with a very loud report, The hand should be covered with a glove in making this experiment, and care should be taken that the phosphorus, in an inflamed state, does not fly into the eyes. Phosphorus may also be inflamed under the surface of water, by means of this salt. Put into a wine glass, one part of phosphorus with two of the salt; fill it nearly with water, and pour in, by means of a glass tube, reaching to the bottom, three or four parts of sulphuric acid. The phosphorus takes fire, and burns vividly under the water. This experiment too requires caution lest the inflamed phosphorus should be thrown into the eyes. (Davy.) Oil may also be thus inflamed on the surface of water, the experiment being made with the omission of the phosphorus, and the substitution of a little olive or linseed oil. H. 1. 516.

831. Chlorate of potassa should not be kept mixed with sulphur in considerable quantity, as the mixture may explode spontaneously.

Substituted for nitre in gunpowder.

832. It was proposed by Berthollet to substitute this salt for nitre, in the preparation of gunpowder and the attempt was made at Essone in 1788; but, as might have been expected, no sooner was the mixture of the chlorate with the sulphur and charcoal submitted to trituration than it exploded with violence, and proved fatal to several people. With phosphorus the detonation is dangerously violent. These phenomena depend upon the decomposition of the chloric acid. The action of sulphuric acid upon chlorate of potassa has already been adverted to (290.) If, instead of distilling the yellow mixture of the acid and chlorate with the caution there described, it be heated to about 150°, it suddenly explodes. The theory of the production of chloric oxide appears to be as follows: the sulphuric acid expels one proportional of oxygen from the chlorate, and the potassium absorbs one proportional to produce potassa, which gives rise to sulphate of potassa; the remaining four proportionals of oxygen and one of chlorine form the oxide of chlorine.

833. A few grains of chlorate of potassa put into a tea-spoonful of muriatic acid, and then diluted with water, form an extemporaneous bleaching liquor.

Composition.

834. Chlorate of Potassa consists of one proportional of chloric acid and one of potassa, or 76 C. A. + 48 P. Its ultimate components, therefore, are

6	proportionals of oxygen . . . in the acid and 1 in the alcali	=48
1	proportional of chlorine	=36
1	———— potassium . . .	=40
		124

Oxychlorate.

835. *Oxychlorate of Potassa—Perchlorate*—may be form-ed by moistening one part of chlorate of potassa with three of ulphuric acid, and subsequently carefully heating the mass till it ecomes white: in this state it consists of bisulphate and oxy-hlorate of potassa, which may be separated by solution and rystallization, the former being much more soluble in cold wa-er than the latter salt.

Oxychlorate of potassa does not change vegetable colours, nor it altered by exposure to air. It requires rather more than parts of water at 60° for its solution. It is insoluble in alco-ol. It crystallizes in elongated octoëdrons. When mixed ith its own weight of sulphuric acid, and distilled at 280°, olution of oxychloric acid passes over. It may be decomposed y exposure to a temperature of 412°. Oxygen is given off, nd chloride of potassium remains in the retort. This salt is hus found to consist of one proportional of oxychloric acid = 2 + one proportional potassa = 48, and its representative num-ber is therefore = 140.

Iodate.

836. *Iodate, and Hydriodate of Potassa.*—Both these salts are formed by agitating iodine with a solution of potassa; water s decomposed, and gives origin to a very soluble hydriodate and a difficultly soluble iodate. The latter may be purified by being washed first with a little water, and afterwards with alcohol sp. gr. ,820, which removes the hydriodate. The iodate remains in small white and granular crystals.

When projected on red-hot coals, iodate of potassa burns like saltpetre; 100 parts heated in a retort give 22,59 oxygen gas, and 77,41 iodide of potassium. It requires for solution 13¼ parts of water at 60° Fahrenheit. It is constituted of 22,246 potassa and 77,754 iodic acid.

Hydriodate.

837. *Hydriodate of Potassa* is deliquescent, and consequently very soluble. It is constituted of 100 hydriodic acid + 37,426 potassa. By crystallization, or simple desiccation, it is changed into iodide of potassium, which is easily fused and volatilized without change at a red heat. H. 1. 517.

Hydruret.

838. *Potassium and Hydrogen.*—When potassium is heated in hydrogen, it absorbs a portion of the gas, and produces a grey and highly inflammable *hydruret.* When hydrogen and potassium are passed together through a white hot tube, the gas dissolves the metal, and produces a spontaneously inflammable *potassiuretted hydrogen gas.* Both these compounds are usu-ally formed during the operation for obtaining potassium by the gun-barrel.

Nitrate.

839. *Nitrate of Potassa—Nitre—Saltpetre.* This salt is an abundant natural product, and is principally brought to this country from the East Indies, where it is produced by lixivation from certain soils.

The rough nitre imported from the East Indies is in broken crystals of a brown colour, and more or less deliquescent: exclusive of other impurities, it often contains a very considerable proportion of common salt, which reacting upon the nitre, induces the production of nitrate of soda and chloride of potassium.

Artificial production of nitre.

840. In Germany and France it is artificially produced in what are termed nitre-beds. Thenard (*Traité de Chemie Élémentaire*, Tom. ii. p. 511.) has described the French process at length. It consists in lixiviating old plaster rubbish, which when rich in nitre, affords about five per cent. Refuse animal and vegetable matter which has putrefied in contact with calcareous soils produces nitrate of lime, which affords nitre by mixture with subcarbonate of potassa. In the same way it is abundantly produced in some parts of Spain. Exudations containing saltpetre are not uncommon upon new walls, where it appears to arise from the decomposition of animal matter contained in the mortar. It was long ago shown by Glauber, that a vault plastered over with a mixture of lime, wood-ashes, and cows' dung, soon becomes covered with efflorescent nitre, and that after some months, the materials yield, on lixiviation, a considerable proportion of that salt.

Nitre crystallizes in six-sided prisms, usually terminated by dihedral summits; it dissolves in 7 parts of water at 60° and in its own weight at 212°. Its taste is cooling and peculiar. It consists of one proportional of acid = 54 + one proportional of potassa = 48. Or of

Composition.

6 proportionals of oxygen . . . . . 5 in the acid and 1 in the alkali .	48
1 proportional of nitrogen	14
1 ——————— potassium	40
	102

841. When exposed to a white heat, nitre is decomposed into oxygen, nitrogen, and dry potassa. By distilling it in an earthen retort, or in a gun-barrel, oxygen gas may be obtained in great abundance, one pound of nitre yielding about 12,000 cubic inches, of sufficient purity for common experiments, but not for purposes of accuracy. It fuses at a heat below redness, and congeals on cooling into cakes called *sal prunelle.*

If the temperature of nitre be so far increased as to allow a portion of oxygen to escape, the remaining salt, as Scheele first observed, remains neutral, and in this state it has been considered as forming a *nitrite of potassa.*

Decomposed by charcoal.

842. Nitre is rapidly decomposed by charcoal at a red heat. This may be shown by mixing two parts of powdered nitre with one of powdered charcoal, and setting fire to the mixture in an iron vessel under a chimney.—If excess of charcoal be used, the results are carbonic oxide and acid, nitrogen, and subcarbonate of potassa, formerly called *nitrum fixum*, and *white flux.*

The old chemists used to perform this detonation in retorts connected with capacious receivers, which were generally blown to pieces; sometimes they succeeded in obtaining a little acidulated water, which they called *clyssus of nitre,* and attributed to it wonderful medical virtues.

843. Nitrate of potassa is also decomposed by sulphur, with different results, according to the temperature and proportions employed. And by sulphur.

Exp. Mix powdered nitre and sulphur, and throw the mixture, by a little at a time, into a red-hot crucible. The sulphur will unite with the oxygen of the nitric acid, and form sulphuric acid; which, combining with the potassa, will afford sulphate of potassa. The production of the latter salt will be proved by dissolving the mass remaining in the crucible, and crystallizing when a salt will be obtained exhibiting the characters of the sulphate.

Exp. Pl. 2. Mix a portion of sulphur with one sixth or one eighth its weight of nitrate of potassa; put the mixture into a tin cup; and raise it, by a proper stand (fig. 36,) a few inches above the surface of water, contained in a flat shallow dish. Set fire to the mixture, and cover it with a bell-shaped receiver. In this case also, sulphuric acid will be formed; but it will not combine, as before, with the alkali of the nitre, which alkali is present in sufficient quantity to absorb only a part of the acid produced. The greater part of the acid will be condensed on the inner surface of the glass bell, and by the water, which will thus become intensely acid. The operation may be repeated three or four times, using the same portion of water. When the water is partly expelled, by evaporation in a glass dish, concentrated sulphuric acid remains. H. 1. 520.

When phosphorous is thrown upon nitre, and inflamed, a vivid combustion ensues, and a phosphate of potassa is formed. Sulphur sprinkled upon hot nitre burns, and produces a mixture of sulphate and sulphite of potassa. This salt used formerly to be employed in medicine. under the name of *Glaser's polychrest salt.* Most of the metals, when in filings or powder, detonate and burn when thrown on red-hot nitre; some of the more inflammable metals produce in this way a considerable explosion.

844. A mixture of three parts of nitre, two of dry subcarbonate of potassa, and one of sulphur, forms *fulminating powder.* If a little of this compound be heated upon a metallic plate, it blackens, fuses. and explodes with much violence, in consequence of the rapid action of the sulphur upon the nitre. Fulminating powder.

845. *Gunpowder* consists of a very intimate mixture of nitre, sulphur, and charcoal. The proportions vary. The following are those usually employed: Gunpowder.

	Common Gunpowder.	Shooting powder.	Shooting powder.	Miners' powder.
Saltpetre . .	75,0	78	76	65
Charcoal . .	12,5	12	15	15
Sulphur . .	12,5	10	9	20

The latter contains the smallest quantity of saltpetre, as it requires less *quickness* or *strength*. The ingredients are *perfectly* mixed, moistened, beaten into a cake which is afterwards broken up, granulated, dried, and for the finest powder polished by attrition. The violence of the explosion of gunpowder depends upon the sudden production of gaseous matter, resulting from the action of the combustibles upon the nitre. Carbonic oxide, carbonic acid, nitrogen, and sulphurous acid, are the principal gaseous results; and the solid residue consists of sub-carbonate, sulphate, and sulphuret of potassa, and charcoal.—CRUICKSHANKS, *Nicholson's Journal*, iv.

Gunpowder may, it is said, be inflamed by a violent blow; if mixed with powdered glass, or any other harder substance, and struck with a heavy hammer upon an anvil, it almost always explodes.

846. *Potassium unites to Sulphur* with the evolution of much heat and light, and forms a grey compound, which, when acted upon by water, produces sulphuretted hydrogen. It consists of 40 P. + 16 S. = 56.

Sulphuret of potassa.

847. *Potassa and Sulphur*, when fused together, form a red *sulphuret of potassa*. (*Liver of Sulphur*.) Its taste is bitter and acrid. It is deliquescent and very soluble in water, forming a yellow solution of *hydrosulphuret of potassa*.

Properties.

It blackens the skin, and turns syrup of violets green, like an alkali. All acids, even the weakest, precipitate sulphur from it, and the stronger acids, when previously diluted, occasion a disengagement of sulphuretted hydrogen gas. The solution absorbs oxygen gas, and has been employed in eudiometry. According to Vauquelin 100 of potassa unite with 111,5 of sulphur. Berzelius finds that 100 parts of the carbonate absorb 93,9 parts of sulphur.

848. Hydro-sulphuret of potassa may be formed by transmitting a current of sulphuretted hydrogen gas through liquid hydrate of potassa, which acquires a yellow colour, and an offensive smell. It forms large transparent crystals, not unlike those of sulphate of soda, but having the shape of four-sided prisms acuminated with four planes, or six-sided prisms acuminated with six planes. It is deliquescent, and runs into a thick syrupy liquor, which gives a green colour to the skin. It dissolves readily in water and alcohol, with a production of cold. On adding any diluted acid, abundance of sulphuretted hydrogen is disengaged, but no sulphur is deposited.

Action on water.

The action of the sulphuret of potassa on water is complicated, and has been variously explained. By some this is considered as a compound of *potassium* and sulphur; in which case, when acted upon by water, hydrogen is imparted to the sulphur, and oxygen to the potassium; and a sulphuret of potassa with excess of sulphur, (or sulphuretted sulphuret of potassa) is formed. If we consider the sulphuret as consisting of *potassa* and sulphur, then, the oxygen as well as the hydrogen of the water, must be transferred to the sulphur, and sulphuric and sulphurous and sulphuretted hydrogen, would be formed; and generally when the solutions of the *livers of sulphur* are examined, sulphate and sulphite of the alkali, are found. On the whole however, it appears most probable, that when sulphur and the alkalies are fused together at a high temperature, the latter undergo decomposition, and that sulphurets of their metallic bases are actually formed.—VAUQUELIN, *Ann. de Chim.*

849. *Hydroguretted sulphuret of potassa* may be formed by boiling flowers of sulphur in liquid hydrate of potassa, or by digesting sulphur with the liquid hydro-sulphuret. The resulting product may be considered as a compound of bi-sulphuretted hydrogen with potassa, in proportions not yet ascertained. By mere solution in water, the sulphuret of potassa is partly changed into this substance. According to Proust, red oxide of mercury, digested with hydroguretted sulphurets, removes the sulphuretted hydrogen, and what remains is a pure liquid sulphuret. H. 1. 528. Hydroguretted sulphuret.

850. *Hypo-sulphite of Potassa.*—This salt is best formed by exposing the hydroguretted sulphuret to the atmosphere, till it has lost its colour, after which, on evaporation, it crystallizes in the form of fine needles; or by decomposing hydro-sulphuret, or hydroguretted sulphuret of potassa by sulphurous acid. The salt has a taste, at first, not unlike that of nitre, succeeded by bitterness, and it is deliquescent. When carefully dried, it takes fire on raising the heat, and burns somewhat like tinder, but with a feeble blue flame. It dissolves chloride of silver, even when very dilute, with great readiness. Hyposulphite.

851. *Sulphite of Potassa* is formed by passing sulphurous acid into a solution of carbonate of potassa till all effervescence ceases, and evaporating out of the contact of air. Rhomboidal plates are obtained, white, of a sulphurous taste, and very soluble. By exposure to air, they pass into sulphate of potassa. Sulphite.

From Dr Thomson's analysis it is constituted in 100 parts, of 2 water + 54,5 base + 43,5 acid; or 100 of sulphurous acid unite with 150 of potash.

852. *Sulphate of Potassa* may be formed by saturating carbonate of potassa, or potassa, with sulphuric acid, and crystallizing the solution. It is a refuse product also of several chemical operations carried on upon a large scale in the processes of the arts. It is the *sal de duobus* of the old chemists: the *potassæ sulphas* of the *U. S. Pharmacopœia*. Its taste is bitter. It crystallizes in short six-sided prisms, terminated by six-sided pyramids. The body of the prism is often wanting and the triangular-faced dodecaëdron results. This salt dissolves in 16 parts of cold, and 5 of boiling water, and in consequence of its difficult solubility, it is thrown down in a white granular powder, when sulphuric acid is added to a moderately Sulphate

strong solution of potassa. Exposed to a red heat it melts, but is not decomposed.

Exp. 853. Sulphate of potassa is decomposed at high temperatures, by charcoal. Mix any quantity of the salt with one fifth of its weight of charcoal finely powdered, and expose the mixture, in a crucible, to a strong heat. The carbon will unite with the oxygen of the sulphuric acid, and will escape in the state of a gas. What remains is a compound, hereafter to be described, of sulphur and potassa, or more probably of sulphur and potassium.*—A sulphuret of potassa. It consists of

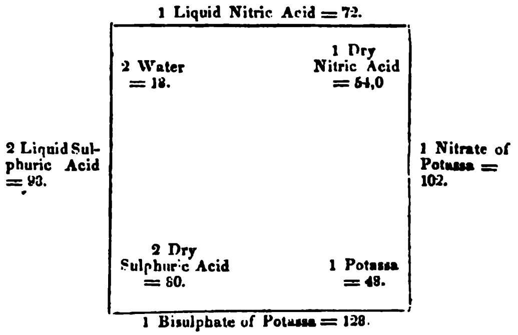
1 proportional of acid = 40
1 ——————alkali = 48
88

Bi-sulphate. 854. ***Bi-sulphate*** or ***Supersulphate of Potassa*** is formed by adding sulphuric acid to a hot solution of sulphate of potassa, or by boiling sulphate of potassa with sulphuric acid. The first crystals which form are in delicate needles of an acid taste, soluble in 2 parts of water at 60°, and consist of

2 proportionals of acid . . = 80
1 —————— potassa = 48
128

Bi-sulphate of Potassa is also formed in the distillation of equal parts of nitre and sulphuric acid: nitric acid passes over, and a residuary bi-sulphate of potassa is produced, commonly known under the name of *sal enixum*. It is the *arcanum duplicatum*, or *panacea Holsatica* of old pharmaceutists. It is used for cleansing coin and other works in metal; and has a place in the *London Pharmacopœia*.

The following diagram will illustrate the formation of this salt, and of liquid nitric acid, in the distillation of two proportionals of sulphuric acid with one of nitre:


1 Liquid Nitric Acid = 72.
2 Water = 18.
1 Dry Nitric Acid = 54,0
2 Liquid Sulphuric Acid = 98.
1 Nitrate of Potassa = 102.
2 Dry Sulphuric Acid = 80.
1 Potassa = 48.
1 Bisulphate of Potassa = 128.

855. ***Ammonia-Sulphate of Potassa*** is a triple salt formed by adding ammonia to bisulphate of potassa. It crystallizes in brilliant plates of a bitter taste.—LINK. *Crell's Annals*, 1796.

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* Vauquelin, *Ann. de Chim. et Phys.* v. 31:

856. ***Phosphuret of potassium*** is a brown compound, which rapidly decomposes water, producing phosphuretted hydrogen gas, and hydrophosphuret of potassa. It is formed by cautiously heating potassium with phosphorus out of the contact of air.

857. ***Hypophosphite of Potassa*** has been examined by Dulong. It is very deliquescent, and soluble in water and alcohol nearly in all proportions. When heated it evolves phosphuretted hydrogen and phosphorus, and is converted into phosphate of potassa.—*Annales de Chim. et Phys.* ii. 142.

858. ***Phosphite of Potassa*** is a soluble deliquescent uncrystallizable salt, not hitherto accurately examined.

859. ***Phosphate of Potassa*** is a soluble, difficultly crystallizable salt. It may be obtained by careful evaporation, in four-sided prisms, and octoëdrons. It contains

1 proportional of potassa . . . . . . = 48
1 ———— phosphoric acid . = 28
76

This phosphate has little taste. By the action of heat it undergoes the igneous fusion. It is not decomposed by lime; unless when the lime is added in considerable excess, and then a compound is formed of phosphoric acid with potassa and lime. The vegetable grains belonging to the *cerealia* contain a small quantity of this salt. It is believed to be a compound of 1 atom of phosphoric acid + 1 atom of potassa. H. 1. 526.

860. *Subphosphate of Potassa.*—When phosphate of potassa is fused in a platinum crucible with potassa it is converted into subphosphate of potassa, which is insoluble in cold, and very difficultly soluble in hot water. It is fusible before the blowpipe, yielding a globule opaque when cold, but transparent whilst in fusion. The theoretical composition of this salt is

2 proportionals of potassa = 96
1 ———— acid = 28
124

861. *Superphosphate or Biphosphate of potassa* is formed by dissolving the neutral phosphate in phosphoric acid and evaporating till crystals are obtained, which are prismatic and very soluble.

862. *Potassa and Carbonic Acid.*—These bodies combine in two proportions, forming the *carbonate* and the *bicarbonate* of potassa, compounds which have been long used and known under various names—such as *fixed nitre*, *salt of tartar*, *salt of wormwood*, *vegetable alkali*, *&c.* Their composition was first ascertained by Black. Bergman, in 1774, described their most essential properties.—*Opuscula*, Vol. ii. p. 13. Carbonate of Potassa.

863. *Carbonate of Potassa* is a salt of great importance in many arts and manufactures, and is known in commerce in different states of purity, under the names of *wood-ash*, *pot-ash*, and *pearl-ash*. It is the *subcarbonate of potassa* of the *U. S. Pharmacopœia*.

Exp.

864. The simplest mode of showing the absorption of carbonic acid by potassa, is the following: Fill a common phial with carbonic acid gas over water; and when full, stop it by applying the thumb. Then invert the bottle in a solution of pure potassa contained in a cup, and rather exceeding in quantity what is sufficient to fill the bottle. The solution will rise into the bottle, and if the gas be pure, will fill it entirely. Pour out the alkaline liquor, fill the bottle with water, and again displace it by the gas. Proceed as before, and repeat the process several times. It will be found, that the solution will condense many times its bulk of the gas; whereas water combines only with its own volume.

Exp.

865. This experiment may be made in a much more striking manner, over mercury, by passing into a jar, about three fourths filled with this gas, a comparatively small bulk of a solution of pure potassa, which will condense the whole of a large quantity of the gas. If dry hydrate of potassa be substituted in this experiment, no change will ensue; which proves that solution is essential to the action of alkalies on this gas. A solution of potassa, which has condensed all the carbonic acid it is capable of absorbing, when evaporated to dryness, affords *sub-carbonate*, or, more properly, *carbonate of potassa*. H. 1. 521.

866. This salt is fusible without decomposition, at a red heat: it is very soluble in water, and deliquesces by exposure to air, forming a dense solution, once called *oil of tartar per deliquium*. Its taste is alkaline, and it renders vegetable blues green. It consists of

Composition.

1 proportional acid = 22
1 ———— potassa = 48
70

The solution of carbonate of potassa will be found to have a much milder taste than the pure alkali, and no longer to destroy the texture of woollen cloth; but it still turns to green the blue infusion of vegetables.

How obtained.

867. For experimental purposes carbonate of potassa may be obtained from crystals of tartar (bi-tartrate of potassa) calcined in a crucible; then lixivated with water, and evaporated to dryness. By this treatment the salt yields about one third its weight of dry carbonate. Or the tartar may be mixed with about an eighth of purified nitrate of potassa, and wrapped up in a paper in the form of cones, which may be placed on an iron dish, and set on fire. The residuary mass is to be lixivated, and evaporated as before directed. Or purified nitrate of po-

tassa may be mixed with a fourth of its weight of powdered charcoal, and projected into a red-hot crucible, the contents of which are to be poured, when in fusion, into an iron dish. The carbonate, thus obtained, amounts to rather less than one half the nitre which has been employed. Even when thus prepared, it is apt to contain some impurities, consisting chiefly of a minute proportion of sulphate and muriate of potassa, with a little silica, from which it is extremely difficult entirely to free it. That which is procured from burnt tartar may be made to crystallize, in which state it contains 20.60 per cent. of water.

Sources of potassa.

868. The great consumption of this article in various manufactures is exclusively supplied by the combustion of vegetables, and consequently its production is almost limited to those countries which require clearing of timber, or where there are vast natural forests. The English market is chiefly supplied from North America. If any vegetable growing in a soil not impregnated with sea-salt be burned, its ashes will be found alkaline from the presence of carbonate of potassa. If the ashes be submitted to heat, so as to burn away the carbonaceous matter entirely, they become a white mass generally termed *pearl-ash*.

Method of determining the quantity of carbonic acid,

869. In the state of union with carbonic acid potassa generally occurs in the arts. The potash and pearlash of commerce are in fact *carbonates* of potassa of different degrees of purity. The quantity of carbonic acid, contained in these alkalies, may be learned by a very simple experiment. Put one or two hundred grains of the alkali into a Florence flask, and add a few ounce-measures of water. Take also a phial filled with dilute sulphuric acid, and place this, as well as the flask, in one scale. Balance the two, by putting weights into the opposite scale, and, when the equilibrium is attained, pour gradually the acid into the flask of alkali, till an effervescence no longer ensues. When this has ceased, the scale containing the weights will be found to preponderate. This shows that the alkali, by combination with an acid, loses considerably of its weight; and the exact amount of the loss may be ascertained, by adding weights to the scale containing the flask and phial, till the balance is restored.

Of detecting adulteration.

870. Carbonate of potassa dissolves very readily in water, which, at the ordinary temperature, takes up more than its own weight.—Hence, when an alkali, which should consist almost entirely of carbonate of potassa, is adulterated, as very often happens, with substances of little solubility, the fraud may be detected by trying how much of one ounce will dissolve in two or three ounce measures of water. In this way may be detected an adulteration of one third its weight of sulphate of potassa. There are certain substances of ready solubility, however, which may be used in adulterating pearlashes, as common salt for example; and, when this is done, we must have recourse to an acid test for the means of discovery. The best, that can be employed for this purpose, is sulphuric acid of sp. gr. 1,141. Of this,

355 grains are equivalent to the saturation of 100 grains of carbonate of potassa. Dissolving therefore, that quantity of the carbonate in water, and gradually adding the test, so as to produce neutralization, we learn, by the quantity of acid expended, the quantity of real carbonate which has been acted upon; for as 355 to 100, so is the weight of the test which has been used to the number required.[*]

The strongest solution of this salt that can be obtained has the specific gravity 1,54, and contains 48,8 per cent. by weight of carbonate, or eight atoms of water to one of salt.

871. According to Vauquelin (*Annales de Chimie*, Vol. xl.) the principal varieties of this substance used in commerce, contain the following ingredients:—

Vauquelin's table.

	Potash.	Sulphate of potash.	Muriate of potash.	Insoluble residue.	Carbonic Acid and water.	TOTA
Potash of Russia	772	65	5	56	254	1152
" America	857	154	20	2	119	1152
American Pearl-ash	754	80	4	6	308	1152
Potash of Treves	720	165	44	24	199	1152
" Dantzic	603	152	14	79	304	1152
" Vosges	444	148	510	34	304	1440

Bi-carbonate.

872. *Bi-carbonate of Potassa* is formed by passing a current of carbonic acid into a solution of the subcarbonate. By evaporation, crystals are obtained in the form of four-sided prisms, with dihedral summits. Their taste is only slightly alkaline, and they require for solution four parts of water at 60°. Exposed to a red heat, carbonic acid is evolved, and carbonate of potassa remains. This bi-carbonate consists of

2 proportionals of carbonic acid = 44
1 ——————— potassa, = 48
92

In its crystalline form it contains water equal to one proportional; and, therefore, consists of

92 carbonate
9 water
101

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[*] The quantity of nitric acid of a given density, requisite to saturate a given weight, may also be resorted to as a criterion of its purity. 100 parts of nitric acid, specific gravity 1,36, will saturate 70 parts of dry carbonate of potassa, which are equivalent to 48 parts of pure potassa.—*Brande.*

In the *London Pharmacopœia* the more expensive method of obtaining this salt by the action of carbonate of ammonia on carbonate of potassa is resorted to.

Preparation.

The following proportions may be used for the preparation of bi-carbonate of potassa upon the large scale: 100 lbs of purified carbonate of potassa are dissolved in 17 gallons of water, which, when saturated with carbonic acid, yields from 28 to 30 lbs of crystallized bi-carbonate; 50 lbs of carbonate of potassa are then added to the mother liquor, with a sufficient quantity of water to make up 17 gallons, and the operation is repeated.

Differs from the carbonate.

873. The *Bi-carbonate of Potassa* differs from the carbonate in the following particulars:

In the greater mildness of its taste. Though still alkaline, yet it may be applied to the tongue, or taken into the stomach, without exciting any of that burning sensation, which is occasioned by the carbonate.

It is unchanged by exposure to the atmosphere.

It assumes the shape of regular crystals. The form of these crystals is a four-sided prism, with dihedral triangular summits, the facets of which correspond with the solid angles of the prism.

It requires, for solution, four times its weight of water at 60°; and, while dissolving, absorbs caloric. Boiling water dissolves five-sixths of its weight; but, during this solution, the salt is partly decomposed, as is manifested by the escape of carbonic acid gas. The quantity thus separated amounts, according to Berthollet, to about $\frac{1}{10}$th the weight of the salt.

By calcination in a low red heat, the portion of carbonic acid, which imparts to the salt its characteristic properties, and all the water are expelled, and the salt returns to the state of carbonate.

Decomposed by acids.

874. Bi-carbonate of potassa, in all its forms, is decomposed by the stronger acids; as the sulphuric, nitric, and muriatic, which unite with the alkali, and set the gas at liberty. This may be shown by pouring on the carbonate, contained in a gas bottle, any of the acids, and collecting the gas by a proper apparatus. H. 1. 525.

Exp.

The sub-carbonate and carbonate of potassa, are both decomposed by lime, which deprives them of carbonic acid; hence the use of that earth in the process for obtaining pure *potassa*.

875. Potassium heated in cyanogen absorbs the gas, and produces a grey *cyanuret of potassium*, which by the action of water becomes *hydrocyanate of potassa*. This salt speedily decomposes, and becomes converted into carbonic acid and ammonia.

Borate.

876. *Borate of Potassa* is a salt which has been scarcely examined; it may be prepared by boiling boracic acid in solution of potassa, or by exposing a mixture of boracic acid and nitre to a bright red heat; it furnishes by solution and evaporation quadrangular prisms, permanent in the air.

Properties of the salts of potassium.

877. The salts of potassium are soluble in water, and afford no precipitates with pure or carbonated alkalies. They produce a precipitate in muriate of platinum, which is a triple compound of potassa, oxide of platinum, and muriatic acid. They are not changed by sulphuretted hydrogen, nor by ferro-prussiate of potassa. Added to sulphate of alumina, they enable it to crystallize, so as to form alum.

Alloys.

878. *Alloys of Potassium.* Potassium combines with several of the metals, forming alloys which are decomposed by water, its oxygen uniting with the potassium and forming potassa, while its hydrogen is disengaged and the other metal precipitated. Several of these alloys have been described by M. Serullas in the *Annales de Chimie et Physique.* (See also Boston *Journal of Philos.* ii. 61.) An alloy of potassium and antimony may be obtained by the following process.

One hundred grains of emetic tartar (*antimonium tartarizatum U. S. Pharmacopœia*) are to be mixed, by careful rubbing, with 3 grains of lamp-black or common charcoal. Select crucibles holding 75 or 80 grains, which must not be more than three quarters filled, make the upper edge smooth, and rub the whole inside with charcoal powder, that the mixture may not adhere to the sides. The materials are to be placed in the crucible, and covered with charcoal powder; the cover is then to be carefully luted on. Place the crucible in a furnace and expose it to a bright red heat for three hours, then set it by for *six hours* to cool. This time is required to allow the air, which always penetrates more or less into the crucible, to burn the exterior layer of the mass; if withdrawn too soon from the fire it always explodes spontaneously. After it has been cooled, the cover of the crucible may be removed, and the calcined mass should, without loss of time, and without breaking up, be introduced into a wide mouthed bottle which should be carefully closed with a ground stopper. The mass gradually splits into fragments of different sizes, and in this state will preserve its properties for years.

Detonation with water.

879. When this alloy has been well prepared it is extremely fulminating, so as to detonate with a report like fire-arms, by the first contact of water.

Inflames gun-powder under water.

880. With this substance gun-powder may be fired under water. The experiment was made in the following manner; half an ounce of gun-powder was put into a strong glass tube closed at one end, of which the powder filled about one quarter. A piece of the fulminating alloy of the size of a pea, was laid upon the powder. The tube was immediately closed with a cork, which had been previously perforated with a small hole, stopped for the present with a little fat lute, soft enough to be readily pierced with a sharp pin when required. The tube thus prepared, was then sunk in a large vessel of water two or three feet deep, and was confined by weights to the bottom. The lute stopping the perforation in the cork was then pierced with

a steel wire fixed to the end of a long stick, and the moment that the water entered the tube the powder exploded, breaking the tube, and throwing out a four-pound weight which had fixed it down.

Other alloys.

881. Several triple alloys of potassium and other metals have also been described by M. Serullas, which may be formed by the following processes.

Potassium, copper and antimony.

882. *Alloy of potassium, copper and antimony.* This is obtained by melting together equal parts of carbonized tartar (prepared by roasting *cream of tartar* of commerce in an open crucible, till it has lost about half its weight) regulus of antimony, and copper filings. The carbonized tartar and antimony should be first rubbed together, and then placed in a crucible the copper filings being laid above them.* The cover of the crucible being luted on, the whole is to be strongly heated for two hours. This alloy has a violet tint, it divides into very thin brilliant laminæ, which flatten a little under the hammer. It is volatile in the fire, and pieces thrown upon mercury, covered with a little water, turn round rapidly.

Of potassium silver and antimony.

883. *Alloy of Potassium, Silver and Antimony,* is prepared like the last; it is more volatile; its colour steel grey, and it has much lustre. It is very brittle, and contains much potassium.

Potassium, iron and antimony.

884. *Alloy of potassium, Iron and Antimony,* is obtained by putting at the bottom of a crucible some iron turnings, broken to small fragments; covering them with equal parts of calcined tartar and antimony, previously mixed, and exposing to a very strong heat.

Potassium and bismuth.

885. *Alloy of Potassium and Bismuth.* Rub together 60 grains of calcined tartar, 120 of bismuth and one of nitre, enclose the mixture in a crucible, covered with lamp-black, close it carefully and heat it for two hours. An alloy is obtained which is very rich in potassium, its smallest fragments giving sparks when cut with shears. As soon as it is broken, it melts and burns, leaving a residue of a greenish oxide.†

If this alloy is made with 10 or 12 grains of lamp-black or charcoal instead of the nitre, a pyrophorus is obtained, which takes fire by the contact of water, and burns with slight explosions. It may be used for kindling gun-powder under water.

Potassium and tin.

886. An *alloy of potassium and tin* is made in the same manner as the preceding, with 100 parts of oxide of tin, 60 of calcined tartar and 10 of lamp-black. A double dose of lamp-black gives a pyrophorus.

Potassium and lead.

887. An *alloy of potassium and lead* is produced by 100 grains of protoxide of lead and 60 of calcined tartar; and an addition of 5 or 6 grains of lamp-black gives a pyrophorus.

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* The copper filings should be previously mixed with a sixth part of antimony to promote their fusion.

† In certain cases this alloy offers an excellent test of the complete desiccation of gas. All that is required is to pass up a small fragment of the alloy to the gas confined over mercury, when the least moisture will cause it to turn round. (S.)

A pyrophorus. M. Serullas remarks that in the preparation of these alloys, the stratum of charcoal put over them to protect them from the action of the air, though in no way mixed with them, acquires the property of spontaneous inflammation in the air; which he conceives can only be attributed to the presence of potassium volatilized during the fusion, and retained by the charcoal.

SECTION II. *Sodium.*

Discovery of sodium. 888. Sodium, discovered by Sir H. Davy in 1808, is obtained from soda by an operation analogous to that for procuring potassium from potassa. (816). It is soft, easily sectile, white and opaque, and when examined under a thin film of naptha has the lustre and general appearance of silver.

Properties. 889. It is exceedingly malleable, and much softer than any of the common metallic substances. When pressed upon by a platinum blade with a small force, it spreads into thin leaves; and a globule of $\frac{1}{10}$th or $\frac{1}{12}$th of an inch in diameter is easily spread over a surface of a quarter of an inch. This property is not diminished by cooling it to 32° Fahrenheit. Several globules, also, may, by strong pressure, be forced into one; so that the property of *welding*, which belongs to platinum and iron at a high degree of heat only, is possessed by this substance at common temperatures.

It is lighter than water; as near as can be determined, its specific gravity is as 0,972 to 1.

890. It is much less fusible than the base of potassa. At 120° Fahrenheit, it begins to lose its cohesion, and is a perfect fluid at 180° or 190°. Hence it readily fuses under heated naptha.

Effect of air. 891. When sodium is exposed to the atmosphere, it immediately tarnishes, and by degrees becomes covered with a white crust of soda, which deliquiates more slowly than that formed on potassium. It is not changed, however, by air that has been artificially dried.

Of oxygen. 892. It combines with oxygen, slowly and without luminous appearance, at all common temperatures. When heated to its fusing point, the combination becomes more rapid; but no light is emitted till it becomes nearly red hot. The flame which it then produces, is white, and it sends forth bright sparks, exhibiting a very beautiful effect. In common air, it burns with a similar colour to charcoal, but with much greater splendour.

Action on water. 893. When thrown into water, it produces a violent effervescence and a loud hissing noise; it combines with the oxygen of the water to form soda; and hydrogen gas is evolved, which does not, however, as in the case of potassium, hold any of the alkaline base in solution. Neither can sodium be made to dissolve in hydrogen gas, by being heated in contact with it.

When thrown into hot water, the decomposition is more violent, and in this case a few scintillations are generally observed at the surface of the fluid; but this is owing to small particles of the base, which are ejected from the water, sufficiently heated to burn in the atmosphere.

894. Its action on alcohol, ether, volatile oil, and acids, is similar to that of potassium; but with nitric acid a vivid inflammation is produced. H. 1. 53. On alcohol.

895. *Sodium and Oxygen.* From the quantity of hydrogen evolved when sodium is thrown into water, we learn that soda (*protoxide of sodium*) consists of about 75 sodium and 25 oxygen *per cent.*; and if it be considered as the protoxide, the number representing the metal will be 24, and *soda* will consist of 24 S. + 8 O. and be represented by 32. Soda.

896. The peroxide of sodium may be formed, by burning the metal with an excess of oxygen. It is of a deep orange colour, very fusible, and a nonconductor of electricity. When acted on by water, its excess of oxygen escapes, and it becomes soda. It deflagrates with most combustible bodies. It appears to be constituted of 2 atoms of sodium = 48, with 3 atoms of oxygen = 24, and its equivalent number is therefore 72. Peroxide.

897. *Soda*, as it usually occurs in the laboratories, is obtained from the carbonate, by the action of lime and alcohol, as described under the head *potassa*. It may also be formed by burning sodium in a quantity of air, containing just oxygen enough to convert the metal into alkali. It is of a grey colour; of a vitreous fracture; and requires a strong red heat for its fusion. It consists of 32 protoxide of sodium + 9 water, and is represented by 41. When soda is exposed to air, it soon becomes covered with an efflorescence of carbonate of soda.

898. Soda is distinguished from potassa, by forming an *efflorescent* paste when exposed to the atmosphere; potassa under the same circumstances *deliquesces*. If excess of tartaric acid be added to a solution of soda there is no precipitation; but in solution of potassa it occasions a deposite of minute crystals. Solution of soda occasions no precipitate when added to solution of muriate of platinum. Solution of potassa occasions a yellow precipitate in solution of platinum. In combination with acids it produces a perfectly distinct class of salts. Distinguished from potassa.

899. *Chloride of Sodium.*—Sodium, when heated in chlorine, burns and produces a white compound, of a pure saline flavour, soluble in 2½ parts of water at 60°, and forming cubical crystals. Chloride.

900. Or it may be formed by saturating carbonate or hydrate of soda with muriatic acid, and evaporating the liquid, which yields chloride of sodium in a solid form. This chloride also, is an abundant produce of nature, being that well known substance, common salt, which is become a necessary ingredient in the food of man, and is of essential utility in several of the arts. For purposes of experiment, the common salt may be employed, Ho obtained.

which is to be found in the shops. This may be purified, by adding to a solution of it in water a solution of carbonate of soda, as long as any milkiness ensues; filtering the solution, and evaporating it till it crystallizes.

Properties. 901. It crystallizes in solid regular cubes, or, by hasty evaporation, in hollow quadrangular pyramids, which, when the salt is pure, are but little changed by exposure to the air. The common salt of the shops, however, being impure, acquires an increase of weight, in consequence of the absorption of moisture. The various forms under which it appears, of stoved salt, fishery salt, bay salt, &c. arise from modifications in the size and compactness of the grain, rather than from any essential difference of chemical composition.

902. It requires for solution, twice and a half its weight of water, at 60° Fahrenheit, and hot water takes up very little more. Hence its solution crystallizes, not like that of nitre, by cooling, but by evaporation. When heated gradually, it fuses, and forms, when cold, a solid compact mass. If suddenly heated as by throwing it on red-hot coals, it decrepitates. It does not, however, after being dried at the temperature of boiling water, lose by ignition more than two or three parts of water *per cent.* and essentially it contains no water. When mixed with powdered charcoal or sulphur, and fused in a crucible, it does not undergo any decomposition or essential change.

Decomposition. 903. It is decomposed by the carbonate of potassa, the alkali of which combines with the muriatic acid of the salt, and the carbonic acid is transferred to the soda.—Hence we obtain muriate of potassa and carbonate of soda. A process for effecting this decomposition, on a large scale, is described by Westrumb, in Crell's Journal, English translation. ii. 127.

904. When chloride of sodium is dissolved in water, it passes, by the decomposition of that fluid, to the state of muriate of soda, and it is this salt and not the chloride of sodium (which last can only exist in a solid form) that is the ingredient of sea water and other solutions of common salt. Muriate of soda is composed, in 100 grains.

Composition.

		Acid.	Base.	
According to Darcet	of	49,27	50,73	
———— Berard	"	43,	57,	
———— Dr Marcet	"	46,	54,	
———— Berzelius	"	46,56	53,44	H.1.537.

Chloride of sodium, as it exists in fused common salt, is constituted of an atom of sodium, weighing 24, with an atom of chlorine weighing 36, and its equivalent is 60. It consists, then, of

Sodium	40,5	100	68
Chlorine	59,5	147	100
	100,	247	168

Dr Wollaston assumes its constitution to be 39,64 sodium + 60,36 chlorine.

905. In the common process for obtaining muriatic acid it is decomposed by sulphuric acid. In this decomposition there is a transfer of the oxygen contained in the water of the sulphuric acid to the sodium of the salt, the chlorine of which combines with the hydrogen of the water to produce muriatic acid gas. The oxide of sodium unites with the dry sulphuric acid to produce sulphate of soda. (371).

Glauber first obtained muriatic acid from common salt, and the existence of soda in it was first shown by Duhamel.

906. *Chlorate of Soda* was procured by Mr Chenevix (*Phil. Trans.* 1802), by the same process as chlorate of potassa, but not possessing less solubility than chloride of sodium, the two substances are difficultly separable. Vauquelin obtained it by saturating chloric acid with soda. Its crystals resemble those of chlorate of potassa, its taste is also nearly similar. Chlorate.

907. *Sodium and Iodine* act upon each other with the same phenomena as potassium, and an *iodide of sodium* is obtained. The hydriodic acid and soda produce a similar compound. It is deliquescent, and its solution yields quadrangular crystals. Iodide.

908. *Iodate of Soda* is made by dissolving iodine in solution of soda; a white compound forms, which is the iodate with a portion of hydriodate of soda; the latter may be removed by alcohol. Iodate of soda forms small prismatic tufted crystals, which when heated, afford oxygen and iodide of sodium.—GAY-LUSSAC, *Annales de Chimie*, xci. Iodate.

909. *Nitrate of Soda* crystallizes in rhombs, soluble in three parts of water at 60°, and in less than its weight at 212°. It has a cool sharp flavour, and is somewhat deliquescent. It consists of 32 soda + 54 nitric acid. It is often found in crude nitre, resulting apparently from the decomposition of common salt; it is the *cubic nitre* of old writers. It may be formed by saturating carbonate of soda with nitric acid, or by distilling common salt with three-fourths its weight of nitric acid. When the former process is adopted, the solution must be evaporated, till a pellicle appears on its surface, and then allowed to cool. Nitrate.

910. The only use of nitrate of soda is, perhaps, that which has been suggested by Proust, who has found it to be more economical in the making of fire works than nitrate of potassa.* † H. 1. 541. Uses.

911. *Hyposulphite of Soda* is formed as hyposulphite of potassa. (849.) It is difficultly crystallizable, deliquescent, of an intensely bitter taste, and insoluble in alcohol. Its aqueous solution readily dissolves moist chloride of silver.

912. *Sulphite of Soda* is crystallizable in transparent four and six-sided prisms, soluble in four parts of water at 60°. It

* Nicholson's *Journal*, xv. 262. See also 6 *Ann de Chim. et Phys.* 206.

† *Sulphuret of Sodium and of Soda.* See *Potassium.* (846). The sulphurets exhibit nearly similar properties.

consists of 32 soda + 32 sulphurous acid. The crystals contain twelve proportionals of water = 108.

Sulphate.

913. *Sulphate of Soda—Glauber's Salt—Sal mirabile*—is abundantly produced in the manufacture of muriatic acid, by the action of sulphuric acid upon common salt.

Composition.

914. Common salt consists of 24 Sodium + 36 chlorine. Sulphuric acid consist of 40 dry acid + 9 water. The water of the acid, consisting of 1 hydrogen + 8 oxygen, is decomposed. Its hydrogen is transferred to the chlorine to produce gaseous muriatic acid (1 H. + 36 C. = 37 Mur. A.), and its oxygen unites to the sodium, forming dry soda (8 Ox. + 24 S. = 32 soda). The 40 dry acid. unite to the 32 soda, to produce sulphate of soda, which will be represented by the number 72.

915. Sulphate of soda crystallizes from its aqueous solution in large four-sided prisms, transparent, and efflorescent, when exposed to air. They consist of 72 dry sulphate + 90 water; exposed to dry air the crystals part with about 50 per cent. of water.

Properties.

The taste of sulphate of soda is saline and bitter: it is soluble in rather less than three times its weight of water at 60°. When exposed to heat it undergoes watery fusion, that is, it melts in its own water of crystallization; when this has evaporated it fuses.

916. Sulphate of soda is sometimes decomposed for the purpose of obtaining soda, by igniting it with chalk and charcoal, or with iron and charcoal. (Of these processes a full account is given in AIKIN's *Dictionary*, Art. *Muriate of Soda.*) Its principal use is in Pharmacy.

Bi-sulphate.

917. *Bi-sulphate of Soda* is obtained by adding sulphuric acid to a hot solution of sulphate of soda. It crystallizes in Rhomboids soluble in twice their weight of water at 60°. This salt consists of 72 sulphate of soda + 40 sulphuric acid = 112. CRELL's *Annals*, 1796.*

Phosphate.

918. *Phosphate of Soda* crystallizes in rhomboidal prisms soluble in four parts of water at 60°, and efflorescing when exposed. It has a pure saline taste. It consists of

32 soda
28 phosphoric acid
——
60

The crystals contain about 62 per cent. of water. This salt is usually obtained for pharmaceutical purposes by saturating the impure phosphoric acid, obtained from calcined bones by sulphuric acid, (See *Phosphorus*) with carbonate of soda: the liquor is filtered, evaporated, and set aside to crystallize. It was introduced into pharmacy by Dr Pearson; it is the *sal perlatum* of some old writers.

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* *Ammonio-sulphate of Soda* is a triple salt, formed by saturating the bi-sulphate with ammonia. Crell's *Annals*, 1796, 1.

Phosphite of Soda has not been examined. *Hypophosphite of Soda* is very soluble both in alcohol and water.—*Annales de Chim. et Phys.* ii. 142.

When heated, phosphate of soda fuses and boils up, and having lost its water of crystallization, it runs into a clear glass, which becomes opaque on cooling. If a globule be heated before the blow-pipe it assumes the dodecaëdral figure as it cools.

919. Treated with sulphuric acid, phosphate of soda is only partly decomposed, a *bi-phosphate of Soda* being formed, which is more soluble than, and not so easily crystallizable as the phosphate.

Ammonio-phosphate.

920. *Ammonio-phosphate of Soda* exists in human urine, whence it was procured by the early chemists under the names of *microcosmic* and *fusible salt.* When exposed to heat the ammonia is expelled, and a *bi-phosphate of soda* remains: it appears to consist of two proportionals of phosphoric acid = 56; one of soda = 32, and one of ammonia = 17.—FOURCROY, *Annales de Chimie,* vii. 183.

Carbonate.

921. *Carbonate of Soda* is chiefly obtained by the combustion of marine plants, the ashes of which afford, by lixiviation, the impure alkali called *soda.* Two kinds of rough soda occur in the market; *barilla,* and *kelp;* besides which, some *native carbonate of soda* is also imported. Barilla is the semifused ash of the *salsola soda,* which is largely cultivated upon the Mediterranean shore of Spain, in the vicinity of Alicant. Kelp consists of the ashes of sea weeds, which are collected upon many of the rocky coasts of Britain, and burned in kilns, or merely in excavations made in the ground and surrounded by stones. It seldom contains more than 5 per cent. of carbonated alkali, and about 24 tons of sea weed are required to produce one ton of kelp. The best produce is from the hardest *fuci,* such as the *serratus, digitatus, nodosus,* and *vesiculosus.* (MAC CULLOCH'S *Western Islands,* Vol. i., p. 122.) The rough alkali is contaminated by common salt, and impurities, from which it may be separated by solution in a small portion of water, filtrating the solution, and evaporating it at a low heat: the common salt may be skimmed off as its crystals form upon the surface.

922. The primitive crystalline form of carbonate of soda is an octoëdron, with a rhombic base; the solid angles of the summit are always wanting, being replaced by planes parallel to the base, and thus presenting a solid with 10 surfaces. It is soluble in twice its weight of water at 70°. Its taste is strongly alkaline, and it greens vegetable blues. It consists of

32	soda
22	carbonic acid
54	

Its crystals contain seven proportionals of water = 63, which may be expelled by heat. They effloresce by exposure to air. This salt is the *Sodæ-Subcarbonas* of the *Pharmacopœia.*

In the analysis of barilla and kelp, to ascertain the relative proportion of soda, it may be useful to know that 100 parts of dilute nitric acid, specific gravity 1,36, will saturate 50 parts of dry carbonate of soda, which are equivalent to about 29 of pure soda.

Bi-carbonate.

923. *Bi-carbonate of Soda* is formed by passing carbonic acid through the solution of the sub-carbonate. By evaporation a crystalline mass is obtained. This salt consists of

32 soda
44 carbonic acid
76

The bi-carbonate of soda has a very slightly alkaline taste, and it is much less soluble in water than the sub-carbonate.

924. This salt, as well as the bi-carbonate of potassa, may be obtained by treating their respective carbonates with carbonate of ammonia; pure ammonia is evolved and bi-carbonates are formed.—(See *U. S. Pharmacopœia*, p. 198. Bigelow's *Sequel*, p. 342.)

Process for obtaining it in the large way.

In the manufacture of this bi-carbonate for the purpose of commerce, 160 lbs. of carbonate may be dissolved in 13 gallons of water, and carbonic acid thrown into the solution in a proper apparatus. The bi-carbonate falls as it forms to the amount of about 50 lbs., and being separated from the solution may be conveniently dried by pressure in an hydraulic press, and subsequent exposure to heat not exceeding 100°. A fresh portion of carbonate is dissolved in the mother liquor, and the operation repeated as before.

925. A mixture of the carbonates of soda occurs native in great abundance in Africa, in the province of Gahena, near Fezzan. The natives call it *Trona*. It has been analyzed by Mr R. Phillips, who considers it as a compound intermediate between the carbonate and bi-carbonate. Or to be constituted of 3 atoms of acid + 2 of soda, or of 1½ atoms of acid = 33 + 1 of soda = 32, together 65. Hence he has given it the name of *sesqui-carbonate of soda*. (*Journ. of Science, &c.* vii. 298.)

A very productive soda-lake also exists in South America in Maracaybo, one of the provinces of Venezuela.—*Quarterly Journal*, i. p. 188.

Borax.

926. *Sub-borate of Soda—Borax.*—This salt, which has been very long known, is imported from India in an impure state, under the name of *Tincal*, which, when purified, is called *refined Borax*. It crystallizes in irregular hexaëdral prisms, slightly efflorescent. Its taste is alkaline and styptic. It is soluble in 20 parts of water at 60°, and in six parts of boiling water. When heated it loses water of crystallization, and becomes a porous friable mass, called *calcined borax*, or *glass of borax*. It consists, according to Gmelin, of

35,6 acid
17,8 soda
46,6 water
100,0 *Ann. Philos.* Vol. 9.

Sulphuric acid decomposes this salt, producing sulphate of soda and boracic acid. (750) It has a place in the *Pharmacopœia*, and is much used in experiments with the blow-pipe.

927. The salts of sodium are soluble in water. They are not precipitated either by pure or carbonated alkalis, or hydro-sulphuret of ammonia, or ferro-prussiate of potassa; they produce no precipitate in solution of muriate of platinum, and do not convert sulphate of alumina into octoëdral alum.

928. Potassium and sodium form an alloy, which, if composed of one part of potassium and three of sodium, remains fluid at 32°. Equal parts of the metals form a brittle crystallizable alloy.

SECTION III. *Lithium.*

929. IN the analysis of a mineral, called petalite, M. Arfwedson discovered about three per cent. of an alkaline substance, which was at first supposed to be soda; but, finding that it required for its neutralization a much larger quantity of acid than soda, he was led to doubt its identity with that alkali, and the further prosecution of his inquiries fully demonstrated that it possessed peculiar properties. The minerals called *spodumene and lepidolite* also afford the same substance, to which the term *lithia*, deduced from its lapideous original, has been applied. It has also been detected in a few other minerals. Discovery.

930. The following is the mode of obtaining lithia.—Reduce the mineral to a fine powder, and fuse it with about half its weight of potassa; dissolve the fused mass in muriatic acid, filter, and evaporate to dryness; digest the dry mass in alcohol; the only substance present, soluble in that liquid, is the *muriate of lithia*, which is taken up; and by a second solution in alcohol and evaporation, it is obtained pure. It may be decomposed by digesting carbonate of silver in its aqueous solution, by which a carbonate of lithia is formed, decomposable by lime, in the way of the other alkaline carbonates. Method of obtaining lithia.

931. M. Arfwedson decomposed petalite by the following method. He strongly calcined, for an hour and a half, the finely powdered mineral with four times its weight of pure carbonate of baryta; digested the product with an excess of muriatic acid, which, leaving the silica undissolved, took up the baryta, alumina, &c.; precipitated the baryta by sulphuric acid, and the alumina by carbonate of ammonia; and then, evaporating to dryness the residuary liquor, and raising the heat so as to expel the ammoniacal salts, a saline residue was left, which was dissolved by water, with the exception of a small quantity of sulphate of lime. It was a neutral salt, consisting of the new substance in combination with sulphuric acid. The sulphate was decomposed by acetate of baryta, and the acetate Arfwedson's method.

of lithia, thus obtained, was converted by calcination into carbonate of lithia.[*] For carbonate of baryta, Vauquelin and Gmelin[†] advantageously substituted the nitrate.

932. When lithia is submitted to the action of the Voltaic pile, it is decomposed with the same phenomena as potassa and soda; a brilliant white and highly combustible metallic substance is separated, which may be called *lithium*, the term *lithia* being applied to its oxide.

The properties of this metal have not hitherto been investigated, in consequence of the difficulty of procuring any quantity of its oxide.

Union with oxygen.

933. The proportion, in which this metal unites with oxygen, has, of course, not been determined by direct experiment; but it has been deduced by Vauquelin, from an analysis of the sulphate of lithia, and the application of the law that the proportion between the oxygen of sulphuric acid and that of the bases which it saturates is as 3 to 1, to be as follows:

Lithium	56,50	100	130
Oxygen	43,50	77	100
	100,		

Arfwedson's estimate scarcely differs from this, but Gmelin deduces the composition of lithia to be 58,05 metal + 41.95 oxygen; and if this be correct, and lithia be constituted of an atom of each of its ingredients, lithium will be represented by 11 and lithia by that number + 8 = 19.[‡] H. 1. 550.

934. Pure lithia is very soluble in water, and its solution tastes acrid like the other fixed alkalies. It acts powerfully on vegetable blues, converting them to green. It is very sparingly soluble in alcohol.

Chloride.

935. *Chloride of Lithium*, obtained by evaporating the muriate to dryness, and fusing it, is a white semitransparent substance. It evidently differs from the chlorides of potassium and sodium, in being extremely deliquescent; in being soluble in alcohol; in being decomposed when strongly heated in the open air, when it loses chlorine, absorbs oxygen, and becomes highly alkaline; in being very difficultly crystallizable; and in tinging the flame of alcohol of a red colour.[||]

Muriate.

936. *Muriate of Lithia* forms small regular cubes very similar to common salt in their taste. The easiest mode of obtaining the crystals is to expose the solution to the sun in a hot day. The crystals deliquesce very speedily when exposed to the air, but not with so much rapidity as nitrate of lithia. This salt does not melt when exposed to the red heat produced by the action of a spirit lamp; but when exposed in a platinum

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[*] Ann. de Chim. et Phys. x. 86.

[†] Ann. of Philos. xv, 341.

[‡] Dr Thomson and Mr Brande make the number for Lithium 10; and that for Lithia 18.

[||] *Nitrate of Lithia* is a very soluble deliquescent salt, fusible and decomposed by heat; its taste is cooling; it crystallizes in rhomboids.

crucible, not completely covered, to an incipient white heat, it is fused into the chloride. U. 565.

Sulphuret.

379. *Sulphuret of Lithium.*—The action of sulphur on lithium and lithia appears analogous to its action on potassium and potassa, it affords a very soluble yellow compound which is decomposed by acids, with the same phenomena as the alkaline sulphurets, and, from the abundance of the precipitate appears to contain a large proportion of sulphur.

Sulphate.

938. *Sulphate of Lithia* crystallizes in small rectangular prisms, perfectly white, and possessed of much lustre. Their taste is saline, and their solubility intermediate between that of sulphate of potassa and sulphate of soda. The crystals contain no water, and fuse at a heat below redness. Their solution occasions no change in solution of platinum, nor in tartaric acid. They consist of

Sulphuric acid	69,18 or	40
Lithia	30,82 or	17,8
	100	57,8[*]

Phosphate.

939. *Phosphate of Lithia* has been examined by Dr Gmelin: it may be obtained by adding phosphoric acid to sulphate of lithia; no precipitate is at first formed, but on adding excess of ammonia, an insoluble phosphate of lithia falls. This property enables us to separate lithia from potassa and soda. The phosphate of lithia may be decomposed by dissolving it in acetic acid and adding acetate of lead: *acetate of lithia* remains in solution.

Carbonate.

940. *Carbonate of Lithia.*—When a strong solution of carbonate of potassa is added to sulphate of lithia, a white precipitate of *carbonate of lithia* is formed. It requires about 100 parts of water at 60° for its solution. It is fusible, alkaline, effervesces with acids, and absorbs carbonic acid from the air. Lithia and its carbonate, when heated upon platinum, act upon that metal.[†]

Composition.

It consists of 54,46 acid + 45,54 base. The watery solution effervesces with acids; changes vegetable blue colours to green; decomposes solutions of alumina and magnesia, and of the metals; is rendered caustic by lime; disengages ammonia from its combinations; and does not precipitate the muriate of platinum.

Distinctive characters.

941. Lithia, then, is sufficiently distinguishable both from potassa and soda, by its difficult solubility in water; by affording deliquescent salts with muriatic and nitric acids; and still more by its higher capacity of saturation. It agrees with soda in not being precipitated by tartaric acid or muriate of platina;

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[*] *Bi-sulphate of lithia* is produced by adding an excess of sulphuric acid to the neutral sulphate. It is more fusible and less soluble in water than the sulphate.

[†] The platinum crucible in which carbonate of lithia has been exposed to a red heat, gives obvious indications of having been attacked, its surface assuming a dark olive-green colour; but the metallic lustre is restored by rubbing the crucible with coarse sand and water.

but the salts of lithia, when their concentrated solutions are mixed with one of carbonate of soda, deposite carbonate of lithia. H. 551.

SECTION IV. *Calcium.*

How obtained.

942. WHEN lime is electrized negatively in contact with mercury, an amalgam is obtained, which, by distillation, affords a white metal. It has been called *calcium*, and when exposed to air, and gently heated, it burns and produces the *oxide of calcium*, or *lime*.*

To obtain calcium, a paste may be moulded, either of pure lime, or of sulphate of lime and water, into the shape of a small capsule, which may be placed on a metallic dish. Into this capsule mercury may be poured, and connected with the negative extremity of a galvanic apparatus of sufficient power, while the positive wire of the same pile is made to touch the under surface of the metallic plate. When the contact has been continued sufficiently long, an amalgam of mercury and calcium is obtained, which may be put into a small retort, along with naptha enough to cover it. The retort is then to be connected with a tubulated receiver, the tubulure of which is only loosely stopped with a cork. On applying heat, the naptha first comes over; then the mercury; and the calcium remains, surrounded by an atmosphere of vapour of naptha. As the vessels cool, it would be desirable, and would not be difficult, to fill them with nitrogen gas, to prevent the oxidation of the calcium. H. 1. 552.

Lime appears to consist of 20 parts of this metallic base united to 8 parts of oxygen, so that its representative number will be = 28.

Native carbonates of lime.

943. The combinations of lime are very abundant natural products, and of these the *native carbonate* which, more or less pure, constitutes the different kinds of marble, chalk, and limestone, and which is also the leading hardening principle of shell, coral, &c., may be considered as the most important.

Method of obtaining lime.

Lime may be obtained in a state of considerable purity by exposing powdered white marble to a white heat, which expels the carbonic acid. To obtain absolutely pure lime, white marble may be dissolved in dilute muriatic acid, a little ammonia added to the solution, and filtered: carbonate of ammonia is then added, and the precipitate dried, washed, and exposed to a white heat.

Properties.

944. Its colour is light grey; it is acrid and caustic and converts vegetable blues to green; its specific gravity is 2,3; it is very difficult of fusion, but remarkably promotes the fusion of most other earthy bodies, and is therefore used in several metallurgic processes as a cheap and powerful flux. When

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* Or *Quick-lime* as it is popularly termed from its corrosive properties.

quite pure it can only be fused in very minute particles by the oxygen blow-pipe, or by the Voltaic flame. It is an essential ingredient in mortar, and other cements used in building. Exposed to air it becomes white by the absorption of water and a little carbonic acid.

Hydrate.

945. When a small quantity of water is poured upon lime, there is a great rise of temperature resulting from the solidification of a portion of the water, and a white powder is obtained, called *slaked lime*, which is a *hydrate*, and which appears to consist of one proportional of water $= 9 +$ one proportional of lime $= 28 = 37$ hydrate.

It is strictly a *proto-hydrate*. Some care is necessary in its preparation, lest more water should be added, than is essential to its constitution. It affords a very convenient form of keeping lime, for occasional use in a laboratory; for the hydrate may safely be preserved in glass bottles, which are almost constantly broken by the earth, if enclosed in its perfectly dry state.

Phenomena attending the slaking of lime.

946. The degree of heat produced by the combination of lime with water, is supposed by Mr Dalton to be not less than 800°, and is sufficient to set fire to some inflammable bodies; and when a large quantity of lime is suddenly slaked in a dark place, even light, according to Pelletier, is sometimes evolved. The caloric, which is thus set at liberty, is doubtless that contained in the water, and essential to its fluidity. By combination with lime, water passes to a solid state, and probably even to a state of much greater solidity than that of ice. Hence, during this change, it evolves more caloric than during conversion into ice; and hence even ice itself, when mixed with quicklime, in the proportion of one to two, enters into a combination which has its temperature raised to 212°. When a sufficient quantity of water has been added to reduce lime into a thin liquid, this is called *milk* or *cream of lime*; but this can scarcely be regarded as a definite compound.

947. Lime, though not of itself volatile, is, in some manner, perhaps mechanically, carried up by the vapour employed in slaking it. When a piece of moistened paper, stained with the juice of the violet, is held in the steam, which arises from lime suddenly slaked, its colour is changed from blue to green. Hence the smell which is perceived during the slaking of lime. H. 1. 554.

948. Lime may be obtained in a crystalline form by placing lime-water under the receiver of an air-pump, with another vessel of sulphuric acid. The water is thus slowly evaporated, and imperfect crystals of hydrate of lime are formed. GAY-LUSSAC, *Annales de Chimie et Phys.* i. 334.

At the temperature of 60°, 750 parts of water are required for the solution of one part of lime.

Lime water.

949. Lime-water is limpid and colourless; its taste is nauseous, acrid, and alkaline, and it converts vegetable blues to green.

It is usually prepared by pouring warm water upon powdered lime, and allowing the mixture to cool in a close vessel: the clear part is then decanted from the remaining undissolved portion of lime. When lime-water is exposed to the air, a pellicle of carbonate of lime forms upon its surface, which, if broken, is succeeded by others, until the whole of the lime is thus separated in the form of an insoluble carbonate. Lime-water is used in medicine as an antacid.

950. When oxygen is passed over heated lime, it is absorbed, and a portion of *peroxide of calcium* is formed. A hydrated peroxide of calcium is thrown down, according to M. Thenard, when lime-water is dropped into oxygenated water.

Chloride of calcium.

951. *Chloride of Calcium* is produced by heating lime in chlorine, in which case oxygen is evolved; or by evaporating *muriate of lime*, obtained by dissolving carbonate of lime in muriatic acid, to dryness, and exposing the dry mass to a red heat in close vessels. In this case the muriatic acid is decomposed; its hydrogen, uniting with the oxygen of the lime, escapes in the state of water; and the chlorine unites with the calcium. The chloride and the muriate are, therefore, mutually convertible by adding or expelling water.

Composition and Properties.

952. It consists of 20 calcium + 36 chlorine = 56. This compound has a strong attraction for water; it deliquesces when exposed to air, and becomes what used to be called *oil of lime*. It is difficultly crystallizable from its aqueous solutions; with care, however, it may be obtained in six-sided prisms, consisting of the chloride combined with water. It is most readily crystallized by exposing its solution to the temperature of 32°. Its taste is bitter and acrid; one part of water at 60° dissolves four parts of the chloride. Its solubility, however, is greatly influenced by temperature, for at 32° one part of water will not dissolve more than two of the salt, and at 212° it takes up nearly any quantity. It is copiously soluble in alcohol, and much heat is evolved during the solution. When fused it acquires a phosphorescent property, as was first observed by Homberg, and hence termed *Homberg's phosphorus*. It is abundantly produced in the manufacture of carbonate of ammonia, from the decomposition of muriate of ammonia by lime, and hence has sometimes been called *fixed sal ammoniac*. The production of cold by mixing muriate of lime with snow has already been adverted to (132.) Chloride of lime absorbs ammoniacal gas in considerable quantities. (FARADAY, *Journal of Science*, Vol. v. p. 74.) In its fused state this compound is very useful for drying certain gaseous bodies, but where the quantity of the gas is to be ascertained, its powers of absorption in certain cases must not be overlooked.

Homberg's phosphorus.

Uses.

Pelletier has stated, that if carbonic acid be passed through a solution of muriate of lime, the whole becomes a hard solid mass. If sulphuric acid be poured into a strong solution of muriate of lime, the whole congeals into a solid mass of sulphâte of lime. (37.)

Exp.

953. A substance called *Oxymuriate of Lime—Sub-chloride of lime* is abundantly employed as a bleaching material, and manufactured by passing chlorine into leaden chambers containing hydrate of lime in fine powder, by which the gas is copiously absorbed. Dr Thomson has shown this to be a compound of chlorine and lime; when heated it gives off a large quantity of oxygen, and a chloride of calcium results. This shows the superior attraction of calcium for chlorine compared to oxygen, the latter being expelled from the lime.*

Chlorate.

954. *Chlorate of Lime* is a very soluble deliquescent salt of a sharp bitterish taste. It is most easily produced by dissolving carbonate of lime in chloric acid. Exposed to heat, oxygen is evolved, and a chloride formed.†

Nitrate.

955. *Nitrate of Lime* is a deliquescent salt, soluble in 4 parts of water at 60°. It is found in old plaster and mortar, from the washings of which, nitre is procured by the addition of carbonate of potassa.

Preparation of

956. To prepare it artificially, nitric acid, diluted with five or six parts of water, may be saturated with carbonate of lime, 63 parts of which are decomposed by 90,23 of nitric acid of density 1,5, and give 103,05 of dry nitrate of lime.‡ When this solution is boiled down to the consistence of syrup, and exposed in a cool place, long prismatic crystals, are formed, resembling, in their disposition, bundles of needles diverging from a common centre. These crystals are readily soluble in water, of which, at 60°, they require two parts, and boiling water dissolves an equal weight. They deliquiate speedily, when exposed to the air; and are decomposed at the temperature of ignition. Exclusive of water it contains,

	Acid.	Base.	
According to Dalton	61,3	38,7	
———— Phillips	65,6	34,4	H. 1. 562.

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* The assay of sub-chloride of lime, in order to ascertain its commercial value, has been effected in several ways. Mr Dalton first proposed detaching the gas from a given weight either of the dry or liquid compound, over mercury in a graduated tube, by means of an acid A portion of the chlorine is retained by the liquid, which may be estimated at twice its volume; but no sensible error is, it seems, occasioned by the action of the chlorine on the mercury. He afterwards announced what he considers as an improved method, *viz.* the successive addition of a solution of the chloride to a solution of green sulphate of iron (sp. gr. 1, 149.) till the smell of chlorine is developed.

This method, however, is greatly inferior to that of liberating the chlorine by an acid. To effect this, without the aid of a mercurial trough, Dr Ure has contrived an instrument described in the Quarterly Journal, xiii. 21. For the purposes of the artist, however, the most practicable method will be found to be the test of solution of indigo in sulphuric acid. It may be of such strength that 1600 parts of the liquor contain one of indigo, Of this solution 100 cubic inches of chlorine = $76\frac{1}{4}$ grains, destroy the colour of 1159,5 cubic inches, or 10 grains of chlorine discharge the colour of 152 cubic inches of the solution. It is desirable to dilute the solution of chloride, so that its volume may be nearly one-half that of the colour test; to pour the former into the latter slowly and at intervals, stirring the mixture well after each addition; and in making several comparative experiments to take care that the quality of the test, and the manner of proceeding, shall be the same in all. It cannot, however, be pretended that this test possesses the scientific accuracy attainable by the admeasurement of the disengaged chlorine, which alone is to be depended upon, when a precise analysis is required. H. 1. 560.

† *Iodate of Lime* is difficultly crystallizable in small quadrangular prisms. *Hydriodate of Lime* is very deliquescent; when dried it becomes *iodide of calcium*, a white fusible compound.

‡ Phillips' *Journal of Science*, v. 167,

Baldwin's phosphorus.

957. When a solution of nitrate of lime is evaporated to dryness in an earthen vessel, then fused for five or ten minutes in a crucible, and poured while in fusion into an iron pot previously heated, the congealed mass forms *Baldwin's phosphorus*. It must be broken into pieces, and preserved in a well-stopped phial. These pieces, after having been exposed to the sun for a few hours, emit in the dark a beautiful white light, affording one variety of solar phosphorus. At a red heat it is decomposed; its acid is dissipated, and pure lime remains. It contains in its crystallized state about 25 per cent. of water, and may hence be considered as composed of

1 proportional dry nitrate	82	
3 ——— water	27	
	109	B.

Sulphuret.

958. *Sulphuret of Lime* is formed by heating in a covered crucible one part of sulphur with two of lime. It is soluble in water with the same phenomena as sulphuret of potassa.

Hydrosulphuret.

959. According to Mr Herschel, crystallized *hydrosulphuret* of lime is formed when three parts of slaked lime and one of sulphur are boiled in twenty parts of water, and the solution allowed to cool upon the sediment: he dried the crystals by exposure to the absorbent power of a large surface of sulphuric acid, placed under an exhausted receiver. Their form is that of quadrilateral prisms with dihedral summits. They are sparingly soluble in cold water, the solution having a yellow colour and an acrid, bitter, and sulphurous taste. They consist of two proportionals of lime, two of sulphur, one of hydrogen, and four of water.—*Edinburgh Philosophical Journal*, i. p. 11, *&c.*

Hyposulphite.

960. When sulphurous acid is ground in a mortar with the above crystals its smell disappears, and when filtered it is found to be a solution of *hyposulphite of lime*. By passing sulphurous acid through an aqueous solution of sulphuret of lime, the same product is obtained: and if the solution be filtered and evaporated, at a temperature not exceeding 140°, it furnishes crystals: the temperature of ebullition decomposes it. The crystals are little altered by air, very soluble in water, and insoluble in alcohol. They consist, according to Mr Herschel, of

Lime	21,71
Acid	36,71
Water	41,58
	100

961. The hyposulphites of soda, potassa, and ammonia, of baryta, and of strontia, may be formed by passing sulphurous acid through the aqueous solutions of their sulphurets.

Sulphite.

962. *Sulphite of Lime* is formed by passing sulphurous acid into a mixture of lime and warm water. It is a white powder, soluble by excess of sulphurous acid, and then separating in

prismatic crystals, of difficult solubility, efflorescent, and passing into sulphate of lime by exposure to air.

Sulphate.

963. *Sulphate of Lime* occurs native in selenite, gypsum, and plaster-stone. Sulphate of lime may be formed, by adding to the carbonate a sufficient quantity of sulphuric acid; and by gently calcining the residue, to expel the redundancy of the latter acid; it then affords silky crystals soluble in 350 parts of water. When these, or the native crystallized sulphate are exposed to a red heat, they lose water, and fall into a white powder (*plaster of Paris*), which, made into a paste with water, soon solidifies. Dry sulphate of lime consists of 28 lime $+$ 40 sulphuric acid $= 68$.

Composition.

Crystalline sulphate of lime contains two proportionals of water, and is consequently represented by $68 + 18 = 86$. As sulphate of lime is more soluble in water than pure lime, sulphuric acid affords no precipitate when added to lime-water. Nearly all spring and river water contains this salt, and in those waters which are called *hard* it is abundant. They curdle soap, the alkali of which is detached by the sulphuric acid, and the oil is set at liberty. It gives to them a slightly nauseous taste. At a very high temperature sulphate of lime is fusible, but it suffers no decomposition; heated with charcoal it is converted into a sulphuret. It dissolves without decomposition in dilute nitric and muriatic acids, and separates from these solutions when concentrated, in long, silky or transparent crystals. It is decomposed by the alkaline carbonates, a double exchange of principles ensuing. Hence the milkiness which ensues on adding carbonate of potassa to many spring waters; the carbonate of lime, which is generated, being less soluble than the sulphate.

Native.

964. *Native Sulphate of Lime* occurs in various forms. The crystallized variety is usually called *selenite;* the fibrous and earthy, *gypsum;* and the granular or massive, *alabaster.* The primitive form of selenite is a *right oblique-angled prism.*[*]

The crystals are commonly transparent, and of various colours; it is softer than native carbonate of lime, and yields very easily to the nail. It is seldom found in veins, but generally disseminated in argillaceous strata. It is often accompanied by shells and pyrites, and appears to have resulted from their mutual decomposition. A beautiful fibrous variety is found in Derbyshire, applicable to ornamental purposes. It is turned by the lathe, and sculptured into a variety of beautiful forms, more especially by the Florentine artists.

Anhydrous.

965. There is a variety of sulphate of lime, which has been called *anhydrous gypsum*, or *anhydrite*, in reference to its containing no water. It is harder than selenite, and sometimes contains common salt, and is then called *muriacite.* It is rarely crystallized, generally massive and lamellar, and susceptible of division into rectangular prisms. It has a pale blue tint; sometimes it is pink or reddish, and often white. It has been

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[*] Brooks' Crystallography

found at Vulpino, in Italy, and hence called *Vulpinite*. The statuaries of Bergamo and Milan employ it, and artists know it by the name of *Marbre di Bergamo*. A compound of sulphate of lime and sulphate of soda is found in the salt-mines of New Castile, which mineralogists have described under the name of *Glauberite*.

Phosphuret.

966. *Phosphuret of Lime.*—By passing phosphorus over red-hot lime, a brown compound is produced, which rapidly decomposes water with the evolution of phosphuretted hydrogen gas. *Hydrophosphuret* and *hypo-phosphite of lime* are also formed.

How prepared.

The best process for obtaining this phosphuret is the following: select a green glass, or porcelain tube, closed at one end, and about 18 inches long, and one inch diameter, and carefully cover it with a clay lute containing a very little borax. Put an ounce of phosphorus broken into small pieces into the lower end, and fill it up with pieces of clean quicklime, about the size of large peas: place it in an inclined position in a furnace, so that the end containing the phosphorus may protrude, while the upper part of the tube is heating to redness; then slowly draw the cool part into the fire, by which the phosphorus will be volatilized, and passing into the red-hot lime, convert a portion of it into phosphuret. Care should be taken that no considerable portion of phosphorus escapes and burns away at the open end of the tube, which after the process, should be corked and suffered to cool. Its contents may then be shaken upon a sheet of paper, and the brown pieces picked out and carefully preserved in a well stopped phial; the white pieces, or those which are only pale brown, must be rejected. This compound, though called phosphuret of lime, is probably a *phosphuret of calcium.*

If the carbonate of lime be substituted for pure lime, the carbonic acid is decomposed. Its carbon is set at liberty, and appears in the state of charcoal; while its oxygen unites with the phosphorus; and the phosphoric acid, thus produced, forms phosphate of lime. In this process, discovered by the late Mr Tennant, carbonic acid is decomposed by the conspiring affinities of phosphorus for oxygen, and of lime for phosphoric acid, though the former affinity only would be inadequate to produce the effect. H. 1. 565.

Properties.

967. The phosphuret of lime has the remarkable property of decomposing water at the common temperature of the atmosphere; and the water afterwards contains phosphite, or hypophosphite, not phosphate of lime.[*]

Exp.

Drop a small piece of it into a wine-glass of water, and in a short time bubbles of phosphuretted hydrogen gas will be produced; which, rising to the surface will take fire, and explode. If the phosphuret of lime be not perfectly fresh, it may be proper to warm the water to which it is added.

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[*] Gay-Lussac, 25 *Ann. de Chim.* 206, and *Ann. de Chim. et Phys.* vi. 328.

Into an ale-glass put one part of phosphuret of lime, in pieces of about the size of a pea (not in powder), and add to it half a part of chlorate of potassa. Fill the glass with water, and put into it a funnel, with a long pipe, or narrow glass tube, reaching to the bottom. Through this pour three or four parts of strong sulphuric acid, which will decompose the chlorate; and, the phosphuret also decomposing the water at the same time, flashes of fire dart from the surface of the fluid, and the bottom of the vessel is illuminated by a beautiful green light. (Davy). Exp.

968. *Phosphate of Lime* exists abundantly in the bones of animals; it is also found in the mineral world. It may be formed artificially, by mixing solutions of phosphate of soda and muriate of lime. It is insipid and insoluble in water, but dissolves in dilute nitric and muriatic acid without decomposition, and is precipitated unaltered by caustic ammonia. It is decomposed by sulphuric acid, and thus the phosphoric acid for the production of phosphorus is usually procured (593.) It consists of 28 lime + 28 phosphoric acid = 56. Phosphate.

969. It may be obtained by dissolving bones, which have been well calcined and then pulverized, in dilute muriatic acid, and precipitating the solution with pure ammonia. The precipitate, when sufficiently edulcorated, is *phosphate of lime.* At a very high temperature phosphate of lime fuses into an opaque white enamel. How obtained.

970. *Bi-phosphate of Lime* is formed by digesting the phosphate in phosphoric acid. On evaporation a white deliquescent uncrystallizable mass is obtained, composed of one proportional of lime + two of phosphoric acid.

971. The phosphoric glass described under the head *phosphoric acid* (594.) is considered by Dr Thomson as a definite compound, which he has termed *quadriphosphate of* lime.—System, ii. 460.

972. *Native Phosphate of Lime* has by some been regarded as a *sub-phosphate*, in which case it would be composed of two proportionals of lime + one phosphoric acid. This compound occurs crystallized and massive, and is known under the names of *apatite*, *asparagus-stone*, and *phosphorite.* Native.

973. *Carbonate of Lime* is the most abundant compound of this earth. Carbonate.

Lime has a strong attraction for *carbonic acid*, but not when perfectly dry; for if a piece of dry quicklime be passed into a jar of carbonic acid gas over mercury, no absorption whatever ensues. But if a bottle, filled with carbonic acid gas, be inverted over a mixture of lime and water of the consistence of cream, a rapid absorption will be observed, especially if the bottle be agitated; or if a jar or bottle, filled with carbonic acid, be brought over a vessel of lime water, on agitating the vessel, a rapid diminution will ensue, and the lime water will become milky. Exp.

When a shallow vessel of lime water is exposed to the air, a white crust forms on the surface, and this, if broken, falls to the bottom, and is succeeded by another, till the whole of the lime is precipitated from the solution. This is owing to the absorption of carbonic acid gas from the air by the lime, which is thus rendered insoluble in water. Dry lime, also, when exposed to the atmosphere, first acquires moisture, and, having become a hydrate, next absorbs carbonic acid. In a sufficient space of time, all the characters distinguishing it as lime disappear, and it acquires the property of effervescing with acids. The strong affinity of lime for carbonic acid enables it to take this acid from other substances. Thus carbonates of alkalies are decomposed by lime (825.) H. 1. 562.

Calcareous spar.

974. Carbonate of lime occurs in nature in great abundance and in various forms. The primitive form of crystallized carbonate of lime, or *calcareous spar*, is an obtuse rhomboid of 105° 5′ and 74° 55′. Its specific gravity is 2,7. It occurs in every kind of rock, and its secondary forms are more numerous than those of any other substance; sometimes it forms fine *stalactites*, of which some of the caverns of Derbyshire furnish magnificent specimens; it is here deposited from its solution in water acidulated by the carbonic acid, and substances immersed in this water become incrusted by carbonate of lime, when the excess of acid flies off, as in the *petrifying well of Matlock*. A fibrous variety of carbonate of lime, called *satin spar*, is found in Cumberland.

Carbonic acid expelled by heat.

975. The carbonic acid existing in carbonate of lime is expelled by a strong red heat. If distilled in an earthen retort, carbonic acid gas is obtained, and lime remains in the retort in a pure or caustic state. By this process carbonate of lime loses about 45 per cent.

Sir James Hall's experiments.

976. The experiments of Sir James Hall have proved, that when the escape of the carbonic acid is prevented by strong pressure, carbonate of lime is fusible in a heat of about 22° of Wedgwood's pyrometer.* And Mr Bucholz has lately fused this substance, by the sudden application of a violent heat, without additional compression.†

Exp.

Decomposed by acids.

977. Carbonate of lime is precipitated by the carbonated alkalies from solutions of muriate, nitrate, and sulphate of lime. It is decomposed by almost all acids. This will appear if upon chalk or marble contained in a gas bottle diluted sulphuric or muriatic acid be poured. A violent effervescence will ensue, owing to the escape of carbonic acid gas, which may be collected over water or mercury. By a little modification of the experiment, the quantity of carbonic acid expelled from the carbonate may be correctly ascertained. Let 100 grains of carbonate be put into a Florence flask, with an ounce or two of water; place this in the scale of a balance; and in the same scale, but in a separate bottle, about half an ounce of muriatic acid. Add

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* Nicholson's *Journal*, xiii. xiv.

† Ibid, xvii. 229.

muriatic acid to the carbonate as long as any effervescence produced, and then blow out that part of the disengaged car- nic acid which remains in the flask, by a pair of bellows. certain, by adding weights to the opposite scale, how much been lost; suppose it to be 43,5 grains; this shows the antity of carbonic acid disengaged. Calcine another 100 ins in a covered crucible. It will lose rather more of its ight; because, besides its carbonic acid, all the water is pelled which it may contain. Let this loss be stated at 45 ains; the former loss deducted from this (45—43,5) or 1,5 ains, shows the quantity of water in 100 of the carbonate. e proportion, however, thus discovered, is so small that it y be considered as an accidental ingredient. Independently water it is constituted,

	Acid.	Base.
According to Dr Wollaston, of....	43,7 ...	56,3
———— Berzelius, of	43,6 ...	51,4

978. *Borate of Lime* is a white tasteless powder of very fficult solubility in water.

979. The salts of lime have the following properties:—

Properties of the salts of lime.

Those which are soluble are not altered by pure ammonia, it they are decomposed by potassa and soda. They are also ecomposed by the carbonates of potassa, soda, and ammonia, hich produce precipitates of carbonate of lime.

Oxalate of ammonia produces in their solutions a white inso- ble precipitate of oxalate of lime, which exposed to a red eat, affords pure lime.

The insoluble salts of lime are decomposed by being boiled ith carbonate of potassa, and afford carbonate of lime.

Fluate.

980. *Fluor Spar.—Fluate of Lime.*—These terms have een applied to a body containing a peculiar principle which has ot hitherto been obtained in an insulated state.

It is a principle which probably belongs to the acidifying lectro-negative supporters of combustion, and which in flour ar is, perhaps, united to calcium. It appears to be united ith hydrogen in the *fluoric* or *hydrofluoric* acid. This pposed base has been called *fluorine* by Sir H. Davy; and *htore* (from φθόριος, *destructive*,) by M. Ampére.

981. Fluor spar is a mineral found in many parts of the orld, but in great beauty and abundance in England, and specially in Derbyshire. Here it is commonly called *Derby- hire spar*, or by the miners of that county *blue John*. It is sually found in cubic crystals, which may easily be cleaved nto octoëdra, sometimes considered as its primitive form (27). ts colours are extremely various. Its specific gravity is 3,15. t is perfectly tasteless and insoluble in water. When thrown powder upon a plate of iron heated below redness in a dark lace, it emits a phosphorescent light.

Compact fluor is a scarce variety: the finest specimens me from the Hartz. A third variety is *chlorophane*, so called from the beautiful pale green light which it exhibits when heated.

The nature of the colouring matter of fluor spar is not exactly understood. It is liable to fade, and the blue varieties become red and brown by heat.

Hydro-fluoric acid.

982. *Hydrofluoric acid* (*hydrophtoric* of Ampère) is procured by distilling a mixture of one part of the purest fluor spar in fine powder, with two of sulphuric acid; sulphate of lime remains in the retort, and a highly acrid and corrosive liquid passes over, which requires the assistance of ice for its condensation.

Method of obtaining.

Fig. 122 represents an apparatus for the formation of this acid. *a* an alembic with a head, from which passes the tube *b* made to fit the neck of the bottle *c*; *d* is a cover which may be substituted for the head when the alembic is used for other purposes, *e* a stopple ground to fit the neck of the bottle *c*. All the parts of this apparatus should be made of pure silver, for glass is instantly acted upon. The alembic may be of the capacity of 16 fluid ounces, that of the head and tube 2½ and that of the receiver 3½ ounces. With an apparatus of this size, about two ounces of pure fluor spar and four ounces of sulphuric acid may be employed. These materials being introduced into the alembic, and the head fitted on, it should be placed under a flue, the bottle or receiver being surrounded with ice and rather loosely connected with the tube. The heat required is not considerable; a few live coals being applied beneath the alembic, the acid will be disengaged, and will condense in the bottle. (SILLIMAN, *Amer. Jour. of Science*, vi. 355.)

983. This acid is colourless, of a very pungent smell and extremely destructive. If applied to the skin it instantly kills the part, producing extreme pain, and extensive ulceration. The fumes instantly and powerfully corrode glass, and the contact of them with the skin, or lungs, should be carefully avoided. At 80° this acid becomes gaseous; it has never been frozen; it produces white fumes when exposed to a moist air, and occasions a hissing noise when dropped into water.

Properties.

984. This acid acts upon potassium and sodium, and some other metals with great energy; hydrogen is evolved, and a peculiar compound, probably the basis of the acid, and the metal, results. These compounds might be called *fluorides.* The principal *hydrofluates, or fluates*, have been examined by Gay-Lussac and Thenard. (*Recherches Physico-chimiques.*) They have not been analyzed, but if we adopt the number 17 as the representative of the acid, considering it as composed of 16 fluorine + 1 hydrogen, it is probable that they consist of one proportional of acid and one of base.

Uses.

985. Hydro-fluoric acid has been used for the purpose of etching on glass, but requires to be diluted with three or four parts of water. The glass should be covered with a varnish, prepared by melting together bees-wax and turpentine, and surrounded

at the edge by a rim of the same. The varnish is then to be removed wherever it is desired to have the acid act upon the glass, as in the usual process of etching on copper. An apparatus for this purpose has been given by Mr Knight. *Philos. Magazine*, xvii. 357.

Hydrofluate of Ammonia.

986. *Hydrofluate of Ammonia* is not crystallizable, and when evaporated loses a portion of alkali and becomes sour: when heated it rises in a dense white vapour.

—of Potassa.

987. *Hydrofluate of Potassa* is a very soluble, deliquescent, and difficultly crystallizable salt, of a sharp taste. When heated it first loses its water of crystallization, then fuses (becoming *fluoride of potassium?*) Sulphuric acid separates the hydrofluoric.

— of Soda.

988. *Hydrofluate of Soda* has less taste, and is less soluble than the preceding. When heated it decrepitates, then fuses. It is permanent in the air, and separates from its solution in hot water, partly as a transparent pellicle and partly in crystals.

989. When hydrofluoric acid is poured into solutions of the salts of lime, a white insoluble powder is thrown down, which resembles fluor spar in its chemical properties, and must therefore be considered as a *fluoride of calcium.*

Fluoboric acid.

990. *Fluoboric Acid.*—This is probably a compound of fluorine with boron, and if regarded as consisting of one proportional of each of its components, its representative number will be 22, and it will contain 16 fluorine + 6 boron. It is gaseous, and may be obtained by heating in a glass retort twelve parts of sulphuric acid, with a mixture of one part of fused boracic acid, and two of fluor spar, reduced to a very fine powder. The gas must be received over mercury: 100 cubical inches weigh 72,5 grains; so that the specific gravity of fluoboric acid compared with hydrogen, is 32,22, and with atmospheric air, 2,400.[*] It produces very copious fumes when suffered to escape into a moist atmosphere; when acted upon by water, which dissolves 700 times its volume, it affords a solution of hydrofluoric and boracic acids, whence it would seem that the hydrogen is transferred to the fluorine, and the oxygen to the boron. It acts with great energy on vegetable and animal bodies, depriving them of moisture and hydrogen. A piece of paper introduced into fluoboric gas becomes instantly charred. Potassium heated in this gas occasions the deposition of boron, and the production of fluoride of potassium, which, by the action of water, becomes hydrofluate of potassa.

Fluoborates.

991. The fluoboric acid combines with different bases, and produces a class of salts which have been called *fluoborates;* of these the *fluoborate of ammonia* has been examined by Dr John Davy. (*Philos. Trans.* 1812.) It appears from his experiments that the fluoboric acid is capable of condensing succes-

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[*] Specific gravity 2,3611 air = 1 } Weight of 100 cubic inches 72,0135. T.
" " 2,125 oxygen = 1 }

sively, one, two, and three volumes of ammonia. The first is a white solid, volatile in close vessels by the application of a gentle heat. The two other compounds are liquid, and when exposed to the atmosphere, lose ammonia and pass into the first.

Section V. *Barium.*

How obtained.

992. To obtain this metal, the earth baryta is negatively electrized in contact with mercury; an amalgam is gradually formed from which the mercury may be expelled by heat, and the metal barium remains; appearing, according to Sir H. Davy, of a dark grey colour, and being more than twice as heavy as water. It greedily absorbs oxygen, and burns with a deep red light when gently heated, producing oxide of barium.

Oxide or Baryta, how obtained.

993. *Oxide of Barium*, *Baryta*, or *Barya*, is obtained by exposing the crystals of nitrate of baryta for some time to a bright red heat. It may also be obtained by decomposing the *native carbonate of baryta.* Let this be powdered, and passed through a fine sieve. Work it up with about an equal bulk of wheaten flour into a ball, adding a sufficient quantity of water. Fill a crucible of proper size, about one third its height, with powdered charcoal; place the ball on this; and surround and cover it with the same powder, so as to prevent its coming into contact with the sides of the crucible. Lute on a cover; and expose it, for two hours, to the most violent heat that can be raised in a wind furnace. Let the ball be removed when cold. On the addition of water, it will evolve great heat, and the baryta will be dissolved. The filtered solution, on cooling, will shoot into beautiful crystals.

Properties.

994. Baryta is of a grey colour, and very difficult of fusion; it appears to consist of 70 barium + 8 oxygen, and is, consequently, represented by 78. Its specific gravity is about 4, hence the name of *Baryta*, as being the heaviest of the substances usually called earths. It eagerly absorbs water, heat is evolved, and a white solid is formed, containing about 10 per cent. of water, which it retains at a red heat; this is the *hydrate of baryta*, and may be considered as a compound of 1 proportional of baryta = 78 + 1 proportional of water = 9, and is, consequently, represented by 87.

Hydrate.

995. *Hydrate of Baryta* dissolves in boiling water, and, as the solution cools, deposits flattened hexagonal prisms, which contain a larger quantity of water, and are easily fusible. According to Mr Dalton, crystallized baryta consists of 1 proportional of baryta, and 20 of water; if it be exposed to air it effloresces into a white powder, containing 1 proportional of baryta and 5 of water; it appears therefore that there are three hydrates of baryta. (*New Chem. Phil.* ii. 522.) The aqueous solution, or *baryta water*, is limpid, colourless, and acts ener-

Baryta water.

getically on vegetable blues and yellows, changing them to green and red; it rapidly absorbs carbonic acid, and deposits an insoluble carbonate of baryta.

Affinity for carbonic acid.

996. Pure baryta has a very powerful affinity for carbonic acid. Let a solution of pure baryta be exposed to the atmosphere. It will soon be covered with a thin white pellicle; which, when broken, will fall to the bottom of the vessel, and be succeeded by another. This may be continued, till the whole of the baryta is separated. The effect arises from the absorption of carbonic acid, which is always diffused through the atmosphere, and which forms with baryta, a substance, *viz.* carbonate of baryta, much less soluble than the pure earth.

Exp.

Or if the air from the lungs be blown, by means of a quill, or tube, through a solution of baryta, the solution will immediately become milky, in consequence of the production of an nsoluble carbonate. The same effect will be produced by mingling with a solution of pure baryta, a little water, impregnated with carbonic acid.

takes it from other bodies.

997. Baryta has so strong an affinity for carbonic acid as even to take it from other bodies. If to a solution of a small portion of carbonate of potassa, of soda, or of ammonia we add the solution of baryta, the earth will detach the carbonic acid from the alkali, and will fall down in the state of a carbonate. By adding a sufficient quantity of a solution of baryta in hot water, the whole of the carbonic acid may thus be removed from a carbonated alkali; and the alkali will remain perfectly pure. H. 1. 578.

Exp.

Alkaline properties.

998. As baryta, like the alkalies, converts vegetable blues to green, and serves as an intermedium between oil and water, it has been called an *alkaline earth*. It has a very acrid, caustic taste, and is highly poisonous. It exists in two natural combinations only, namely, as sulphate and carbonate.

Peroxide.

999. When baryta is heated in oxygen, or when oxygen is passed over baryta, heated to redness in a glass tube, the gas is absorbed and a grey compound is obtained, which is the *peroxide of barium;* consisting of

1 proportional of barium 70 + 2 oxygen 16 = 86.

Thenard's process for obtaining peroxide of hydrogen.

1000. By dissolving peroxide of barium in muriatic acid, and precipitating by sulphuric acid, M. Thenard succeeded in obtaining a new and singular compound of oxygen and water, to which the term *peroxide of hydrogen* may be applied. The solution of the peroxide of barium, and the subsequent separation of the protoxide is repeated a sufficient number of times, in the same portion of dilute muriatic acid; sulphate of silver is then added to separate the muriatic acid, and the sulphuric, which then becomes its substitute, is ultimately removed by baryta. M. Thenard, in his elaborate essay upon this new compound, has shown that the process, although in theory sufficiently simple, presents many practical difficulties, chiefly arising from the impurities contained in the peroxide of barium. To obtain this substance pure, upon which the success of the subsequent operations depends, he gives the following directions. Prepare a very pure nitrate of baryta, and decompose it by a strong heat in a porcelain vessel, by which baryta, containing a portion of silica and alumina, but free from manganese, will be obtained; the latter impurity must always be most cautiously avoided, for oxide of manganese possesses the property of energetically decomposing the oxygenated water.

The baryta, broken into small pieces, is then introduced into a luted glass tube (the glass should not contain lead) large enough to contain about two pounds of it, and being heated to dull redness, a current of dry and perfectly pure oxygen gas is passed through it which it rapidly absorbs; this operation is to be continued till the oxygen escapes from a small tube inserted into the opposite extremity of the larger one.

The peroxide thus obtained is pale grey, and frequently some pieces are speckled with green, which announces the presence of manganese, and which should be rejected: its distinctive character is, that it crumbles when a few drops of water are added to it without producing heat.

The process then proceeds as follows. Take a certain quantity of water (about eight ounces for instance), and add to it a sufficiency of pure and fuming muriatic acid to dissolve about 230 grains of baryta: put this acid liquor into a glass vessel, which during the operation must be surrounded by ice: then take about 185 grains of the peroxide, rub it into a fine paste with a little water in an agate mortar, and put it into the acid liquor with a box-wood spatula; it soon dissolves without effervescence: to this solution add pure sulphuric acid drop by drop, stirring it with a glass rod, till it is in slight excess, which is known by the readiness with which the sulphate falls: then dissolve a second portion of the deutoxide and precipitate as before, taking care to use enough but not too much sulphuric acid. The liquor is now to be filtered, and the residue washed with a little water, so as to keep up the original measure by adding it to the first portion: a second and third washing of the residue with very small quantities of water may be advisable, and these liquors should be kept apart for the purpose of washing the filters in subsequent operations.

A fresh portion of the peroxide is then dissolved in the filtrated liquor and decomposed as before, filtering at every two operations and washing the filter with the savings of the others. We thus proceed till the water is sufficiently oxygenated: when about two pounds of the peroxide have been consumed the water will be united to about thirty times its volume of oxygen, which is as much as it will retain, unless some muriatic acid be added, in which case M. Thenard has made it retain 125 volumes.

When the water is sufficiently oxygenated, it is retained in the ice, and supersaturated with the peroxide of barium, which occasions the separation of flocculi of silica and alumina, coloured with a little oxide of iron and of manganese; the whole is then filtered as quickly as possible, and returned into the vessel surrounded by ice, the baryta is separated by sulphuric acid, and pure sulphate of silver is added to separate the muriatic acid, upon which the liquid, before milky, becomes suddenly clear. The sulphuric acid is ultimately separated by baryta, the liquor filtered and placed in a shallow vessel, under the air-pump receiver, containing a basin of sulphuric acid; the receiver being exhausted, the water evaporates and is absorbed by the acid, while the peroxide of hydrogen being less vaporisable remains; if it give out any oxygen, which sometimes happens from its containing impurities, a drop or two of weak sulphuric acid prevents its further evolution.

The peroxide of hydrogen thus concentrated has the following properties; its specific gravity is 1,45; it is colourless and inodorous; it blisters the cuticle of the tongue, and has a peculiar metallic taste. It does not congeal when exposed to cold, unless diluted. It is rapidly decomposed at a heat below 212°, and very slowly at ordinary temperatures; it may be long kept at 32°. It is decomposed by the pile with the same phænomena as water. It is decomposed by all metals except iron, tin, antimony, and tellurium: the metals should be finely divided, or in powder: silver and oxide of silver decompose it very suddenly with the evolution of heat and light; platinum and gold produce the same phænomena; lead and mercury slowly separate the oxygen. Orpiment and powdered sulphuret of molybdenum act upon it with the same violence as silver; the peroxides of manganese and of lead, also, occasion its instant decomposition. *Traité de Chim.* ii. 41.

Chloride of Barium.

1001. *Chloride of Barium* may be obtained by heating baryta in chlorine, in which case oxygen is evolved: or more easily, by dissolving carbonate of baryta in diluted muriatic acid. The iron and lead, which are occasionally dissolved, along with the baryta, may be separated by the addition of a small quantity of liquid ammonia, or by boiling and stirring the solution in contact with a little lime; or which is still better, by solution of baryta in water. When filtered and evaporated, the solution yields regular crystals, which have most commonly the shape of tables, or of eight-sided pyramids applied base to base.

Properties.

1002. These crystals dissolve in five parts of water, at 60°, or in a still smaller quantity of boiling water, and also in alcohol. They are not altered by exposure to the atmosphere; nor are they decomposed, except partially, by a high temperature. The sulphuric acid separates the muriatic; and the salt is also decomposed by alkaline carbonates and sulphates.

Composition.

1003. The dry salt Sir H. Davy considers as a compound of 1 atom of barium $= 70 + 1$ atom chlorine $= 36$, hence its representative number is 106; and it consists of chlorine 34, barium $66 = 100$. H. 1. 575. The taste of chloride of barium is pungent and acrid; when exposed to heat, the water of crystallization separates, and the dry chloride enters into fusion.

Chlorate of Baryta.

1004. *Chlorate of Baryta.*—To prepare this salt, chlorine gas must be received into a warm solution of baryta in water, till the baryta is saturated. The solution is to be filtered, and boiled with phosphate of silver, which decomposes the common muriate of baryta, and at the same time composes two insoluble salts, phosphate of baryta and chloride of silver. Vauquelin finds the addition of acetic acid recommended by Chenevix, objectionable, and that the compounds of chloric acid are liable, if acetic acid has been employed, to detonate violently when heated. To judge when enough of the phosphate of silver has been used, add to a portion of the filtered liquor, a few drops of nitrate of silver, which, in that case, ought not to disturb its transparency. If too much phosphate of silver has been used, a drop or two of muriatic acid will discover it, and, in that case, the cautious addition must be made of some of the original solution, set a part for the purpose, to which no phosphate of silver has been added. It is from solution of chlorate of baryta, thus carefully prepared, that chloric acid is obtained by the intervention of sulphuric acid (295.) H. 1. 576. It crystallizes in
Composition. quadrangular prisms, soluble in four parts of water, at 60°; and consists of

1 proportional of baryta 78, + 1 prop. chloric acid 76 = 154.

Its solution, when pure, is not precipitated by nitrate of silver or muriatic acid.*

Iodate.

1005. *Iodate of Baryta* may be formed by adding iodine to solution of baryta, from which the iodate precipitates in the state of a white powder, and may be edulcorated by washing with distilled water. When strongly heated it evolves oxygen and iodine, and baryta remains. It consists of

100 acid + 46,34 base.

Nitrate.

1006. *Nitrate of Baryta* may be prepared by dissolving the native carbonate in nitric acid, evaporating to dryness, re-dissolving, and crystallizing; it forms permanent octoëdral crystals.† Its taste is acrid and astringent. It is soluble in 12 parts of cold and 4 of boiling water; it is decomposed by a bright red heat, furnishing pure baryta. It consists of 78 baryta + 54 nitric acid = 132.

The crystals contain two proportionals of water, or 132 dry nitrate + 18 water.

If a moderately strong solution of the nitrate of baryta be added to nitric acid, a precipitation of nitrate of baryta takes place, in consequence of the abstraction of water by the acid;

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[*] *Iodide of Barium* is easily formed by acting upon baryta by hydriodic acid, and evaporating the solution. It may also be formed by heating baryta in hydriodic gas; water and iodide of barium are the results.

[†] If the artificial carbonate be employed, it should be previously well washed with distilled water, till the washings cease to precipitate nitrate of silver. A solution of nitrate of baryta mixed with one of nitrat[illegible]d continue perfectly transparent. H.

ence in using nitrate of baryta as a test of the presence of ılphuric acid in nitric acid, (437) the latter should be considera- ly diluted previous to its application.*

Hyposul-phite.

1007. *Hyposulphite of Baryta.*—This salt is thrown down n pouring muriate of baryta into a solution, not too dilute, of yposulphite of lime; it is a white powder soluble without decomposition in muriatic acid; at a low heat it takes fire and the ulphur burns off. When the solutions from which it is precipi- ted are dilute, it falls, after some minutes, in small crystalline rains, followed by a copious separation of the salt.—HERSCHEL, *Edin. Philos. Journal*, i. 20.

Sulphite.

1008. *Sulphite of Baryta* is insoluble in water, and formed y adding sulphite of potassa to muriate of baryta.

Hyposul-phate.

1009. When sulphurous acid gas is passed into water holding eroxide of manganese in suspension, a neutral solution is ob- ained, composed of sulphate and hyposulphate of manganese. These salts are decomposed by excess of baryta, and a soluble *yposulphate of baryta* is formed, through which carbonic acid s passed, in order to saturate any excess of baryta; and the whole being heated to drive off carbonic acid, which holds a little f the carbonate in solution, the hyposulphate of baryta is obtain- d, and may be purified by crystallization. The solution of this salt may be decomposed by the careful addition of sulphuric acid, and the *hyposulphuric acid* is thus obtained in solution.

1010. This acid is inodorous, sour, and may be concentrated by exposure to a vacuum with sulphuric acid: it is decomposed by a heat below that of boiling water, sulphurous acid is disengaged, and sulphuric acid remains. It perfectly saturates bases, nd forms soluble salts with baryta, strontia, lime, oxide of lead, nd probably with all other bases. (*Annales de Chim. et Phys.* . 312.) The hyposulphate of baryta crystallizes in quadrangu- ar prisms variously terminated; 100 parts of water at 60° dis- olve about 14 parts. It consists of

Composition.

1	proportional of baryta	= 78
1	——— hyposulphuric acid	= 72
2	——— water 9 × 2	= 18
		168

Or it may be stated as comprising in its dry state

	1 baryta	= 78
Hyposulphuric acid	1 sulphuric acid	= 40
	1 sulphurous acid	= 32
		150

Sulphate.

1011. *Sulphate of Baryta* is an abundant natural product; t is insoluble and therefore produced whenever sulphuric acid or a soluble sulphate, is added to any soluble salt of baryta; hence the solutions of baryta are accurate tests of the presence of sulphuric acid. Sulphate of baryta consists of one proportional of sulphuric acid and one of baryta.

40 sulphuric acid + 78 baryta = 118.

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* *Sulphuret of Barium* is a brown compound, which acts upon water as already described, roducing *hydrosulphuret of baryta*.

Native sulphate.

1012. *Native Sulphate of Baryta, Heavy Spar*, or *Baroselenite*, is principally found in the mines of Westmoreland and Cumberland, and in Transylvania, Hungary, Saxony, and Hanover. A variety met with in Derbyshire, is called *cawk*. It occurs massive, and crystallized in a great variety of forms. Its primitive figure is a rhomboidal prism, the angles of which are 101° 42′, and 78° 18′. It is harder than carbonate of lime, but not so hard as fluate of lime. Its specific gravity is 4,7.

Bologna phosphorus.

When native sulphate of baryta is heated it decrepitates, and at a high temperature, fuses into an opaque white enamel: it was employed in the manufacture of *jasper ware* by the late Mr Wedgwood. When heated to redness, it acquires the property of phosphorescence. This was first ascertained by Vincenzo Cascariolo, of Bologna, whence the term *Bologna phosphorus* is applied to it.* This kind of phosphorus, after being exposed for a few minutes to the sun's rays, shines in the dark sufficiently to render visible the dial of a watch. This property is lost by repeated use, in consequence of the oxygenation of the sulphur; but it may be restored by a second calcination.

The artificial sulphate of baryta is used as a pigment, under the name of *permanent white*. It is very useful for marking phials and jars in a laboratory. Sulphate of baryta is sparingly soluble in sulphuric acid.

Methods of obtaining pure baryta from native sulphate.

1013. As the native sulphate is a common and abundant compound, several processes have been contrived for obtaining from it pure baryta. This may be effected by reducing the crystallized sulphate to a fine powder, and heating it red hot for half an hour in a silver crucible with three parts of carbonate of potassa,† the fused mass is then boiled repeatedly in water, till it no longer affords any thing soluble in that liquid;

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* To prepare this substance the native sulphate, powdered after being ignited, is to, be formed into a paste with mucilage of gum arabic, and divided into cylinders or pieces of one fourth of an inch in thickness. These, after being dried in a moderate heat, are to be exposed to the temperature of a wind furnace, placed in the midst of the charcoal. When the fuel is half consumed, it must be replenished, and suffered to burn out. The pieces will be found, retaining their original shapes, among the ashes, from which they may be separated by the blast of a pair of bellows. They must be preserved in a well-stopped phial. H. 1. 534.

† Sulphate of baryta is decomposed by alkaline carbonates, either by fusing a mixture of one part of the finely powdered sulphate with three of carbonate of potassa or soda, or by boiling together the pulverized sulphate and a solution of carbonate of potassa. Respecting this decomposition some curious facts have been ascertained by Dulong and by Mr R. Phillips. (54). When sulphate of baryta is boiled, for two hours, in contact with precisely its equivalent quantity of carbonate of potassa, (that is, with the quantity which ought, from theory, to produce entire decomposition) only one fourth of the sulphate of baryta is converted into carbonate. Reversing the process, and boiling together equivalent quantities of carbonate of baryta and sulphate of potassa (the mutual decomposition of which could not have been expected from the established order of affinities) it was found that, out of 85 parts of carbonate of baryta, 57 had been changed into sulphate. It is obvious, therefore, that the entire decomposition of sulphate of baryta by carbonate of potassa can never be expected, so long as the carbonate of baryta, formed by the mutual action of these two salts, remains in contact with the sulphate of potassa generated at the same time, for this will reconvert the carbonate of baryta into sulphate Nor will any quantity of carbonate of potassa, that can be employed, be adequate to the entire decomposition of sulphate of baryta.

By this process carbonate of baryta, may, however, be procured in sufficient quantity for the purpose of preparing the pure earth and various salts, when the native carbonate cannot be had in sufficient abundance. H. 1 583.

Henry's process.

the insoluble residue, consisting chiefly of carbonate of baryta, may be digested in dilute nitric acid, by which nitrate of baryta is formed, and which will yield the pure earth by exposure to heat. The following method has been recommended by Dr Henry. The sulphate of baryta is to be finely powdered, mixed with three or four times its weight of carbonate of potassa, and boiled with a proper quantity of water for a considerable time, in an iron kettle, stirring it, and breaking down the hard lumps, into which it is apt to run, by an iron pestle. It is then to be washed with boiling water, as long as this acquires any taste. On the addition of dilute muriatic acid, a violent effervescence will ensue, and a considerable portion of the earth, probably along with some metals, will be dissolved. To the saturated solution, add solution of pure baryta in water, as long as it disturbs the transparency of the liquor. This will throw down any metals that may be present; and the excess of baryta may afterwards be precipitated in the state of a carbonate, by a stream of carbonic acid. Decompose the muriatic solution by any alkaline carbonate; let the precipitated earth be well washed with distilled water; and if the pure baryta is to be obtained from it, let it be treated as directed page 272.

Another.

Another method consists in exposing to a red heat, in an earthen crucible, a mixture of six parts of finely powdered sulphate of baryta, with one of powdered charcoal, for half an hour. This converts the sulphate into sulphuret of baryta, which is to be dissolved in hot water, the solution filtered and mixed with solution of carbonate of soda as long as it occasions a precipitate, which when washed and dried, is carbonate of baryta. Or, by adding muriatic acid to the liquid sulphuret, sulphur is thrown down and sulphuretted hydrogen evolved, and muriate of baryta formed, which may be filtered off, and if required, decomposed by carbonate of potassa. Or the sulphuret, as it comes out of the crucible, may be thrown into dilute nitric acid, by which sulphuretted hydrogen is evolved, and a nitrate of baryta formed, which may be separated from the remaining impurities by copious washings with hot water.

Phosphuret.

1014. *Phosphuret of Barium* is produced by passing phosphorus over heated baryta; there is an intense action and a phosphuret of a metallic lustre is obtained, which acts upon water, and affords a solution containing *Hypophosphite of Baryta.*—See (598).*

Phosphite.

1015. *Phosphite of Baryta* was obtained by Berzelius by adding muriate of baryta to phosphite of ammonia; a crust of phosphite of baryta was formed in 24 hours, consisting of

Phosphorous acid	24,31
Baryta	67,24
Water	8,45†

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* *Hypophosphite of Baryta*, like the other hypophosphites, is very soluble and scarcely crystallizable.

† *Ann. de Chim. et Phys.* ii. 231.

Phosphate.

1016. *Phosphate of Baryta* consists of

28 phosphoric acid
78 baryta
———
106

It is insoluble in water; and, therefore, formed by adding a solution of phosphoric acid or phosphate of soda to nitrate or muriate of baryta.

Berzelius has described a crystallizable *Bi-phosphate of Baryta*, obtained by digesting the phosphate in phosphoric acid; and a *Sesqui-phosphate*, obtained by pouring the bi-phosphate into alcohol, which occasions a precipitate of a white tasteless powder composed of 1 proportional of baryta + 1,5 proportional of acid.

Carbonate.

1017. *Carbonate of Baryta* is found native. Artificially produced, it is a white compound insoluble in water, containing

22 carbonic acid + 78 baryta = 100.

It is poisonous.

Native.

1018. Native carbonate of baryta was first discovered at Anglesark, in Lancashire, by Dr Withering, and hence acquired the name of *Witherite*. Its primitive crystal is an obtuse rhomboid: sometimes it forms pyramidal six-sided prisms. It is useful as a source of pure baryta and its salts, and though not soluble in water, is poisonous. It dissolves very sparingly in solution of carbonic acid, whence the superiority of baryta water to lime water in some cases as a test of carbonic acid. The native carbonate of baryta is much more difficult of decomposition by heat than the artificial; if mixed with a little charcoal powder, and kept for some time in a red heat, carbonic oxide escapes, and pure baryta is formed.

Seleniate.

1019. *Seleniate of Baryta.* Selenic acid is capable of uniting with baryta in two proportions. The neutral salt, which is insoluble, consists of 100 acid + 137,7 base; the *biseleniate* which crystallizes in round transparent grains, and is soluble in water, is composed of 100 acid + 68 base.*

Ferro-cyanate.

1020. *Ferro-cyanate of Baryta* may be formed by adding prussian blue to a heated solution of baryta in water, till it ceases to be discoloured. The filtered solution deposits yellowish crystals, which have the figure of rhomboidal prisms, and are soluble in 1920 parts of cold, or 100 parts of boiling, water. They dissolve in nitric and muriatic acids. It consists of 1 proportional of acid 54 + 1 of base = 78 + 2 water 18 = 150. H. 1. 584.

1021. The soluble barytic salts furnish white precipitates of carbonate and sulphate of baryta, upon the addition of carbonate or sulphate of soda. They give a yellow tinge to the flame of spirit of wine. The sulphate is insoluble in nitric acid and in the alkalies, and very sparingly soluble in sulphuric acid.

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* *Borate of Baryta* is an insoluble white powder.

Nearly all the barytic compounds are poisonous ; the safest ntidote is solution of sulphate of soda, or dilute sulphuric acid.)RFILA. *Traité des Poisons*, Tom. i. 2me. p. 167.) The uriate of baryta has been employed in medicine, but the prin- ipal use of baryta is in the chemical laboratory. It is possible at pure baryta might be economically used for the decompo- tion of sulphate of soda, to obtain the pure alkali.

SECTION VI. *Strontium.*

1022. THIS metal is procured from the earth strontia by the me process as barium, which metal it resembles in appear- nce.

Strontia, how obtained.

1023. *Oxide of Strontium*, or the earth *Strontia*, is so alled from Strontian in Scotland, where it was first discovered combination with carbonic acid. It may be prepared either y subjecting the carbonate to a strong heat in a crucible, or by gniting the nitrate in a porcelain retort or other close vessel. grey substance remains which becomes very hot on the affu- ion of water; and when more water is added and heat applied, considerable proportion of the earth is dissolved. On cooling, he solution deposits regular crystals : but the shape of these liffers considerably from that of barytic crystals. The crystals f strontia are thin quadrangular plates, sometimes square, ftener parallelograms. Sometimes they assume a cubic form. I. 1. 585.

Composition.

1024. According to Prof. Brande, Strontia consists of 1 pro- ortional Strontium 47+1 oxygen 8=55. Sir H. Davy, from ndirect experiments is disposed to regard it as composed of bout 86 strontium+14 oxygen in 100 parts.

Properties.

1025. Pure strontia has a pungent, acrid taste, and when pow- ered in a mortar, the dust that rises irritates the lungs and ostrils. Its specific gravity approaches that of baryta. It re- uires rather more than 160 parts of water at 60° to dissolve t; but of boiling water much less. On cooling the crystals eparate.

1026. The crystals of strontia give a blood red colour to the lame of burning charcoal. The solution of strontia changes the egetable blues to a green. U. 722.

1027. Strontia does not combine with alkalies. Baryta has o affinity for it, for no precipitation ensues on mixing the vatery solutions of the two earths. H.

Chloride.

1028. *Chloride of Strontium* may be formed either by eating strontia in chlorine gas which disengages oxygen; or y dissolving carbonate of strontia in muriatic acid and evapo- ating to dryness. It consists of 1 proportional strontium 47+ of chlorine 36=83.

Muriate. 1029. The chloride may be converted into *muriate* by the action of water. It crystallizes in long, slender hexagonal prisms, which are soluble in two parts of water at 60° and to almost any amount in boiling water. In a very moist atmosphere they deliquiate. They dissolve in alcohol and communicate to its flame a blood red colour.

Chlorate. 1030. *Chlorate of Strontia* may be obtained by the direct action of chloric acid on carbonate of strontia. It is a deliquescent salt, having an astringent taste. It detonates when thrown upon red-hot coals with a beautiful purple light.

Iodide. 1031. *Iodide of Strontium* may be formed as iodide of barium (p. 268). Dissolved in water, and carefully evaporated, it furnishes delicate prismatic crystals of *Hydriodate of Strontia*, which, heated in close vessels, fuses, and becomes iodide of strontium by loss of water.*

Nitrate. 1032. *Nitrate of Strontia* may be obtained in the same manner as the nitrate of baryta; it crystallizes in octoëdra and dodecaëdra, and is soluble in its weight of water at 60°. Exclusive of water, this salt consists, according to Richter of 51,4 acid + 48,6 base: or according to Stromeyer of 50,62 acid + 49,38 base. The proportions deducible from the weights of the atoms of its ingredients are 51 acid + 49 base†. H. 1. 588.

1033. Its taste is pungent and cooling. At a red heat the acid is evolved and partly decomposed, and pure strontia remains.‡

Sulphuret of Strontium. 1034. *Sulphuret of Strontium* may be formed by fusing strontia and sulphur in a green glass tube; or by exposing the powdered sulphate to a red heat with charcoal. It dissolves in water with the same phenomena as sulphuret of potassa, and its solution furnishes, by cautious evaporation, crystals of *hydrosulphuret of strontia.*

Hyposulphite of Strontia. 1035. *Hyposulphite of Strontia* is formed by passing sulphurous acid into the liquid sulphuret: it crystallizes in rhomboids permanent at common temperatures and soluble in about 5 parts of water at 60°. (GAY-LUSSAC, *Annales de Chimie*, lxxxv.) According to Mr Herschel, this salt is doubly refractive. Its taste is bitter, and it is insoluble in alcohol. *Sulphite of Strontia* has not been examined.

Sulphate. 1036. *Sulphate of Strontia* occurs native. It is nearly insoluble, 1 part requiring 4000 of water for its solution. (3840 boiling, H.) When heated with charcoal, its acid is decomposed, and *sulphuret of strontia* is formed, which affords nitrate by the action of nitric acid. This process equally practicable upon sulphate of baryta (1013), is sometimes adopted to obtain the earth. Sulphate of strontia dissolves in hot sulphuric acid, but is thrown down upon adding water. It consists of

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* *Iodate of Strontia* is a very difficultly soluble compound; it is resolved at a red heat into oxygen iodine and strontia.

† 52 strontia + 54 nitric acid = 106. *Brande.*

‡ This salt is used in the *red fire* employed at the theatres, which consists of 40 parts of dry nitrate of strontia, 13 powdered sulphur, 5 of chlorate of potassa, and 4 of sulphuret of antimony. The chlorate and sulphuret should be separately powdered, and mixed together on paper with the other ingredients; a very small quantity of powdered charcoal may also be added.

55 Strontia
40 Acid
—
95* (B.)

Native.

1037. The *Native Sulphate of Strontia* is sometimes of a blue tint, and has hence been called *celestine*. Sometimes it is colourless and transparent. Its primitive form is a prism of 104° 48′ and 75° 42′ with a rhomboidal basis. Fine crystallized specimens are accompanied with native sulphur, from Sicily.

Magnificent crystals are found on Strontian Island in Lake Erie.† ‡ Its specific gravity is 3,2.

Phosphate.

1038. *Phosphate of Strontia* may be formed by mixing solutions of muriate of strontia and phosphate of soda. It is insoluble in water, but soluble in an excess of phosphoric acid (which is not the case with phosphate of baryta); it is fusible by the blow-pipe into a white enamel, and decomposable by sulphuric acid. By igniting it with charcoal, *phosphuret of strontium* is obtained. It consists of 1 proportional of strontia 55 + 1 of acid 28 = 83.‖ B.

Carbonate.

1039. *Carbonate of Strontia.* The relation of strontia to carbonic acid resembles, very nearly, that of baryta, and similar experiments may be made with its solution.

Discovery.

1040. Carbonate of strontia is found native, and was first discovered in 1787 at Strontian in Scotland, whence the name of this earth. It was first examined by Professor Hope of Edinburgh in 1791. His experiments are detailed in the *Philosophical Transactions* of the *Royal Society of Edinburgh*, Vol. iv. p. 44.

Native.

1041. The *native* carbonate of strontia has a greenish tint, and occurs in radiated masses, and sometimes in acicular and hexaëdral crystals. Its specific gravity is 3,6.

Properties and composition.

1042. The carbonate of strontia requires for solution 1536 parts of boiling water. The artificial carbonate, according to

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* According to a considerable majority of the chemists who have analyzed it, sulphate of strontia consists of

Acid	42	100
Strontia	58	138
	100	238

From these numbers its equivalent has been deduced by Dr Wollaston. But Vauquelin has stated, that it is composed of 46 acid and 54 base, and Stromeyer of 43 acid and 57 base. The theoretical constitution of 1 atom of acid + 1 of base would require it to consist of 43,60 acid + 56,40 of base. H.

† Discovered by Major Jas. Delafield. See *Amer. Jour. of Science*, Vol. iv. p. 279.

‡ *Hypophosphite of Strontia* has been examined by Dulong: it is a very soluble and difficultly crystallizable salt. *Phosphite of Strontia* has not been examined.

‖ According to Stromeyer it consists of Acid 36.565
Base 63.435

Stromeyer[*] does not essentially contain any water. It consists of

Strontia . . .	70,313 or	100
Carbonic acid .	29,687	42,22
	100.	

These scarcely differ from its theoretical proportions, *viz.* 1 proportional strontia 52, + 1 carbonic acid 22 = 74.

When strongly heated with charcoal powder, it is decomposed, carbonic oxide is given off, and pure strontia remains.[†]

1043. There is in many respects a resemblance between strontia and baryta which has led to confusion in analysis.

Points of resemblance between strontia and baryta.

The following are some of the most striking points of resemblance. They are both found native in the states of sulphate and carbonate only; both sulphates are soluble in excess of sulphuric acid, and nearly insoluble in water; they are decomposable by similar means, as well as the native carbonates: they are both crystallizable from their hot aqueous solutions, and both attract carbonic acid. The carbonates are each soluble with effervescence in most of the acids; but the native carbonates are not so easily acted on as the artificial. Pure ammonia precipitates neither one nor the other.

Distinctions.

The following are essential distinctions. Baryta and all its salts, except the sulphate, are poisonous. The corresponding strontitic salts are innocent. Baryta tinges flame yellow; strontia, red. Strontia has less attraction for acids than baryta, hence the strontitic salts are decomposed by baryta. The greater number of the barytic salts are less soluble than those of strontia, and they differ in their respective forms and solubilities. Pure baryta is ten times more soluble in water than pure strontia.

SECTION VII. *Magnesium.*

1044. THE metallic base of magnesia has not hitherto been obtained; but, when that earth is negatively electrized with mercury, the resulting compound decomposes water, and gives rise to the formation of *magnesia*. From the properties of the amalgam it appears that it is a white solid metal heavier than water, and highly attractive of oxygen.

Magnesia.

1045. *Magnesia or Oxide of Magnesium* is concluded, from indirect experiments, to consist of 12 metal + 8 oxygen; its representative number, therefore, is 20. It may be procured by exposing the carbonate of magnesia to a red heat. Magnesia is a white insipid substance, which slightly greens the blue of violets. Its specific gravity is 2,3; it is almost infusible and insoluble in water. I once succeeded in agglutinating a small rtion of this earth in the voltaic flame, and whilst exposed to is high temperature, it was perfectly fused by directing upon the flame of oxygen and hydrogen. (BRANDE.) A mixture magnesia and lime is scarcely more fusible than the pure rth. It does not absorb carbonic acid or moisture, as is the se with the other alkaline earths.

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[*] Ann de Chim. et Phys. iii. 396.

[†] *Borate of Strontia* was formed by Dr Hope. It is a white powder soluble in 130 parts of water.

Magnesia is by no means a rare production of nature, for ough very seldom found in a state approaching to purity, yet enters largely into some rocks that compose extensive formans, such as serpentine, steatite, &c.: and in combination with lphuric and muriatic acids it forms a large proportion of the gredients of sea-water. Its principal use is in medicine.

Native Hydrate.

1046. *Native Hydrate of Magnesia* is found at Hoboken, New Jersey, its colour is white inclining to green; its texture nellar and soft. It is dissolved in acids without effervescence, d consists of 70 magnesia, 30 water.

Chloride.

1047. *Chloride of Magnesium* may be obtained by passing lorine over red-hot magnesia; oxygen is expelled, and a subnce obtained which moisture converts into muriate of magsia.

Muriate.

1048. *Muriate of Magnesia* is very deliquescent, and diffilty crystallized. Its solution has a bitter saline taste. Exsed to heat and air, muriatic acid flies off and the magnesia mains pure. It consists of

Magnesia . . . 20 Muriatic acid 37.

1049. Muriate of Magnesia is found in a few saline springs, d constitutes about one eighth of the solid ingredients of the ter of the ocean.[*] By evaporating a pint of sea-water we tain

Common Salt . . .	180,5 grs.	Sulphate of Magnesia . . .	15,5	226,1[†]
Muriate of Magnesia	23	Sulphate of Lime	7,1	

The average specific gravity of sea-water is 1,026 or 1,028. freezes at about 28,5°, and does not appear materially to ffer in composition in different latitudes, provided it be taken m a sufficient depth. Near the mouths of rivers, and in the inities of melting ice or snow, its composition will of course ry.[‡]

Hydriodate.

1050. *Hydriodate of Magnesia* is deliquescent and abandons acid when heated. When *iodine* is heated along with magsia and water, both hydriodate and iodate of magnesia are form- . By concentrating the solution, both salts are partly decomsed; and a flocculent *iodide of magnesia* is formed, which en heated, loses part of its iodine, and is changed into a subdide. H. 1. 593.

Iodide.

Nitrate.

1051. *Nitrate of Magnesia* may be prepared by dissolving rbonate of magnesia in diluted nitric acid. The solution, en evaporated, yields crystals in the shape of prisms, with

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Philos. Trans. 1810.

Murray's Analysis of Sea-Water, Edinburgh Phil. Trans. Vol. viii. p. 205.

Chlorate of Magnesia is a bitter deliquescent salt.

four oblique faces truncated at their summits. Most commonly, however, it forms a shapeless mass, consisting of an immense number of small needle-shaped crystals, crossing each other irregularly. These crystals deliquiate in the air, and are soluble in half their weight of water. When exposed to the heat of ignition, they fuse; a few bubbles of oxygen gas first escape; and the nitric acid then passes undecomposed. The salt contains, exclusive of water, according to Dalton, 69 acid + 31 base.*

Ammonio-Nitrate.

1052. *Ammonio-Nitrate of Magnesia* may be obtained by evaporating a mixed solution of nitrate of ammonia and nitrate of magnesia; it forms prismatic crystals of a bitter acrid taste, soluble in about 11 parts of water at 60°, and less deliquescent than their component salts separately. FOURCROY, *Annales de Chimie*, iv. 215.

Sulphuret.

1053. *Sulphuret of Magnesia.*—Sulphur and magnesia do not appear to form a complete sulphuret, for when melted together the compound does not dissolve in water; and when heated the sulphur burns off.

Hyposulphite.

1054. *Hyposulphite of Magnesia* may be formed by boiling flowers of sulphur in solution of sulphite of magnesia; it is bitter, very soluble, but not deliquescent. Being more soluble in hot than cold water, it readily crystallizes as its solution cools; heated, it burns with a blue flame, and by a sufficient continuance of the heat, the whole of the acid is expelled, and magnesia remains.

Sulphite.

1055. *Sulphite of Magnesia* is prepared by passing sulphurous acid through water containing diffused magnesia. It forms tetraëdral crystals soluble in 20 parts of water at 60°.

Sulphate.

1056. *Sulphate of Magnesia* is a commonly occurring compound of this earth, much used in medicine as an aperient.† It is largely consumed in the preparation of carbonate of magnesia. It crystallizes in four-sided prisms with reversed dihedral summits; or four-sided pyramids. Its taste is bitter. It is soluble in its own weight of water at 60°. When exposed to a red heat, it loses its water of crystallization, amounting to about 50 *per cent.*, but is not decomposed. It consists of

Magnesia . . . . 20 . . . Sulphuric acid 40 = 60.

Composition.

In its crystallized state, it may be considered as composed of 1 proportional of dry sulphate + 7 proportionals of water, or 60 sulphate + 63 water = 123.

How obtained.

1057. This salt is usually obtained from sea-water, the residue of which, after the separation of common salt, is known by the

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$$^{*}\left.\begin{array}{l}\text{Magnesia } 20\\ \text{Nitric acid } 54\end{array}\right\} = 74 \text{ Brande.}$$

† When highly concentrated sulphuric acid is suddenly added to fresh prepared and pure magnesia very great heat and vapour are excited, accompanied frequently with an extrication of light: an appearance first observed by Westrumb. But if the carbonate of magnesia be added to diluted sulphuric acid, the carbonic acid is expelled, and a solution of sulphate of magnesia is formed, which crystallizes on evaporation and cooling. H. 1. 597.

name of *bittern*, and contains sulphate and muriate of magnesia; the latter is decomposed by sulphuric acid: a portion of muriate of magnesia often remains in the sulphate and renders it deliquescent: it is also occasionally obtained from saline springs; and sometimes by the action of sulphuric acid on magnesian limestone. It was once procured from the springs of Epsom in Surrey, and hence called *Epsom salt*. It has been found native, constituting the *bitter salt* and *hair salt* of mineralogists: it not unfrequently occurs as a fine capillary incrustation upon the damp walls of cellars and new buildings.

Adulteration how detected

1058. The sulphate of magnesia of commerce is occasionally adulterated with small crystals of sulphate of soda; the fraud is detected by the inferior weight of the precipitate, occasioned by adding carbonate of potassa; 100 parts of pure crystallized sulphate of magnesia furnishing a precipitate of about 40 parts of dry carbonate.

Ammonio-Sulphate.

1059. *Ammonio-Sulphate of Magnesia* may be obtained by mixing solution of sulphate of ammonia with solution of sulphate of magnesia; or by pouring ammonia into a solution of the sulphate of magnesia, in which case, part only of the magnesia is thrown down, the remainder forming with the sulphate of ammonia this triple salt It crystallizes in octoëdra and consists of 68 sulphate of magnesia + 32 sulphate of ammonia = 100.*

Phosphate.

1060. *Phosphate of Magnesia* is formed by adding the carbonate of magnesia to phosphoric acid. It is insoluble. According to Fourcroy, crystals of phosphate of Magnesia may be obtained by mixing the aqueous solutions of phosphate of soda and sulphate of magnesia. The *bi-phosphate* crystallizes in irregular six-sided prisms, soluble in 14 parts of water at 60°, and efflorescent.

Ammonio-Phosphate.

1061. *Ammonio-phosphate of Magnesia* is formed by mixing the solutions of phosphate of ammonia, and phosphate of magnesia; it precipitates in the form of a white crystalline powder, or in small four-sided prisms, tasteless, and scarcely soluble in water, but readily soluble in dilute muriatic acid. Exposed to a high temperature it falls into powder, evolves ammonia, and fuses with difficulty. According to Fourcroy, it contains equal weights of phosphate of ammonia, phosphate of magnesia, and water.

Dr Wollaston's method of separating magnesia.

To separate magnesia from other earths, Dr Wollaston availed himself of the formation of this triple phosphate. A mixture, for instance, of lime and magnesia may be dissolved in muriatic acid; and, upon the addition of bi-carbonate of ammonia, the lime is thrown down in the state of carbonate, but the magnesia is retained by the excess of carbonic acid. Filter and add a saturated solution of phosphate of soda, and in a short time the ammonio-magnesian phosphate falls down, 100 grains of which are equivalent to about 20 of magnesia. In occasionally em-

* Fourcroy, *Annales de Chimie*, vi.

ploying this process, however, I have never been able to throw down the whole of the magnesia, a portion being under all circumstances retained in solution. **Brande.**

Carbonate,

1062. *Carbonate of Magnesia.* Pure magnesia does not attract carbonic acid with nearly the same intensity as lime. Hence magnesia may be exposed to the air without any important change in its properties, or much increase of weight, unless the exposure be long continued, when it first becomes a hydrate by absorbing water, and then attracts carbonic acid from the atmosphere.

Process for obtaining.

The carbonate of magnesia of the shops is prepared by mixing together concentrated and hot solutions of carbonate of potassa and sulphate of magnesia. The sulphate of magnesia thus formed is removed by copious washing with water, and the carbonate of magnesia is then dried. The proportions employed are filtered solutions of 4 parts of the crystallized sulphate and 3 of the carbonate of potassa. One hundred parts of the desiccated sulphate give about 71 of carbonate of magnesia, or about 33 of the pure earth. H. 1. 598. It is a white, insipid, and insoluble powder, which loses its acid at a red heat, and thus affords pure magnesia. It contains

20 magnesia + 22 carbonic acid = 42. B.

1063. Water at 60° dissolves only 1-2493d of its weight, and at the boiling temperature, 1-9000th part, of common carbonate of magnesia.[†] The addition of almost any acid to the carbonate expels its acid, and a compound remains of magnesia with the new acid which has been added. The affinity of carbonic acid appears, indeed, to be feeble, for it is expelled by a very moderate heat, much inferior to that required for the decomposition of carbonate of lime. The residue is pure magnesia, which, for medical and chemical uses, is always prepared by the calcination of the carbonate, and hence its name of *calcined magnesia*. H. 1. 595.[‡]

Decomposed by acids and heat.

1064. Carbonate of magnesia was first used in medicine early in the last century. It is often obtained from sea-water, after the separation of its common salt. It is found *native* constituting the mineral called *magnesite*. It has been found at Hoboken, New-Jersey, in veins in a serpentine rock, accompanying the native hydrate. It is generally white and friable, and in some places in fine acicular crystals.

Native.

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[*] Fourcroy, Annales de Chimie. iv.

Sulphate of Potassa and Magnesia forms rhomboidal crystals, scarcely more soluble than sulphate of potassa, and of a bitter taste.

[†] Edin. Philos. Jour. v. 305.

[‡] When the common carbonate is calcined in the large way, it appears as if boiling, from the extrication of carbonic acid; a small portion ascends like a vapour, and is deposited in a white powder on the cold bodies with which it comes into contact; and in a dark place, toward the end of the operation it shines with a bluish phosphoric light.

As the magnesia of the shops is sometimes adulterated with chalk, this may be detected by the addition of a little sulphuric acid diluted with eight or ten times its weight of water, as this will form with the magnesia a very soluble salt, while the sulphate of lime will remain undissolved. Calcined magnesia should dissolve in this dilute acid without any effervescence. U. 31.

Saturated carbonate.

1065. The saturated carbonate of magnesia (as it has generally been considered,) may be obtained, by passing streams of carbonic acid gas through water, in which common magnesia is kept mechanically suspended, or by adding a very dilute solution of carbonate of soda, highly charged with carbonic acid under pressure, to a dilute solution of sulphate of magnesia. No immediate precipitation ensues, but, after a few days, congeries of crystals will be found adhering to the inner surface of the glass vessel.* H. 1. 594. According to Berzelius these crystals consist of 29,583 base, 31,503 acid, 38,914 water. Dr Henry conceives their true composition to be as follows, and that the existence of a *bi-carbonate of magnesia*† has not been proved, *viz.*

Composition.

1 atom of magnesia	20	28,60
1 atom of carbonic acid	22	32,
3 atoms water	27	39,40
	69	100,

Borate.

1066. ***Borate of Magnesia*** may be formed artificially. It occurs native in a mineral called *boracite*, hitherto only found in the duchy of Luneburgh. Its primitive form is the cube, but the edges and angles are generally replaced by secondary planes, and four of the angles are always observed to present a greater number of facets than the other four; these crystals become electric by heat; the most complex angles being rendered positive, and the simplest negative. It sometimes contains lime.

Carbonate of magnesia and potassa.

1067. ***Carbonate of Magnesia and Potassa***—Berzelius has described a salt with double base, which may be formed by mixing bi-carbonate of potassa in excess, with muriate of magnesia.‡ No precipitate appears, but in a few days the salt arranges itself in crystalline groups on the sides of the vessel. It consists of

Potassa	18,28
Magnesia	15,99
Carbonic acid	34,49
Water	31,24
	100,

1068. The salts of magnesia are for the greater part soluble in water, and afford precipitates of magnesia, and of carbonate of magnesia, upon the addition of pure soda, and of carbonate of soda. Phosphate of soda occasions no immediate precipitate when added to a magnesian salt, but the addition of ammonia causes a white precipitate of the triple ammonio-magnesian phosphate.

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[*] *Magnesia water—Liquid magnesia*; is prepared by adding three drachms of carbonate of magnesia to one gallon of water; the liquid is then impregnated with carbonic acid by means of a forcing pump. (*U. S. Pharmacop.*)

[†] According to Professor Brande "*bi-carbonate*" of magnesia contains 20 magnesia 44 carbonic acid = 64.

[‡] Edin. Philos. Jour. ii: 67.

1069. The minerals which contain magnesia are generally soft and apparently unctuous to the touch; they have seldom either lustre or transparency, and are generally more or less of a green colour.

Separation of magnesia and lime.

1070. The separation of magnesia and lime is a problem of some importance in analytical chemistry, as they often exist together in the same mineral, more especially in the varieties of magnesian limestone. When solution of carbonate of ammonia is added to the mixed solution of lime and magnesia in nitric or muriatic acids, carbonate of lime falls, and the magnesia is retained in solution and may be separated by boiling: this method, however simple, is not susceptible of great accuracy, for a portion of carbonate of lime will always be retained along with the magnesia in solution, and a triple ammoniaco-magnesian salt is also formed. The following process is recommended by Professor Brande. To the mixed solution of lime and magnesia add oxalate of ammonia slightly acid, collect the precipitate, wash and dry it. 65 parts indicate 28 of lime. If nitric or muriatic acid were used for solution, the magnesia may afterwards be obtained by evaporation and heating the residue to redness in a platinum crucible till it ceases to lose weight. If sulphuric acid were the solvent, the same operation affords dry sulphate of magnesia of which 60 parts are equivalent to 20 magnesia.*

M. Longchamp has published a valuable paper on this subject, in the 12th vol. of the *Ann. de Chim. et Phys.* He considers sub-carbonate of ammonia as the best re-agent for separating the two earths. Care must be taken to filter the solution from the calcareous precipitate, shortly after the addition of the sub-carbonate. If it stand 12 or 18 hours, sub-carbonate of magnesia falls with the carbonate of lime. 100 parts of solution of pure muriate of lime gave, with sub-carbonate of ammonia 1,5475 parts of carbonate of lime; 100 of the same solution, previously mixed with muriate of magnesia in excess, yielded 1,5585 parts. Alkaline sub-carbonates dissolve the sub-carbonate of magnesia; but caustic potash precipitates magnesia perfectly, either with or without heat. He objects to the method of separating these earths by first converting them into sulphates; first on account of the great difficulty of driving off the water from the sulphates of magnesia; secondly, from the difficult solubility of heated and dry sulphate of magnesia in water; and thirdly because the sulphate of magnesia is partly decomposed at very high heats. U. 571.

SECTION VIII. *Manganese.*

1071. THE common ore of manganese is the black, or peroxide, which is found native in great abundance. The metal is

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* For the process recommended by Mr R. Phillips, see Quarterly Journal, Vol. vi. 317.

Process for obtaining metallic manganese.

obtained by mixing this oxide, finely powdered, with pitch, making it into a ball, and putting this into a crucible, with powdered charcoal, one-tenth of an inch thick on the sides, and one-fourth of an inch deep at the bottom. The empty space is then to be filled with powdered charcoal, a cover is to be luted on, and the crucible exposed, for one hour, to the strongest heat that can be raised. Mr Faraday has succeeded in obtaining metallic manganese in large globules from the triple tartrate of manganese, by heating it in a crucible in a wind furnace *per se*. (H.) It is of a bluish white colour, very brittle, and difficult of fusion. When exposed to air it becomes an oxide. Its specific gravity is 8,013. It is not attracted by the magnet, except when contaminated with iron.

Oxide.

1072. *Manganese and Oxygen.* There is a diversity of opinion among chemists as to the number of oxides of manganese, and their composition. According to Sir H. Davy there are only two;[*] Mr Brande admits three, Thenard four,[†] and Berzelius five.[‡]

Protoxide.

The *protoxide* may be obtained by digesting the native black oxide in muriatic acid. Chlorine is abundantly evolved, and the hydrogen of the muriatic acid unites with part of the oxygen of the oxide to produce water. The metal thus partly deoxidized, is dissolved by the remaining muriatic acid, forming a *muriate of manganese*. Iron is almost always present, which, as Mr Hatchett has shown, may be easily separated by neutralizing the muriatic solution with ammonia. The oxide of iron is directly precipitated, but oxide of manganese remains in solution, and may be separated by *excess* of ammonia.[§] The solutions of peroxide of manganese furnish a white precipitate with the alkalies, which is a *hydrated oxide of manganese*, and which, when dried in close vessels, acquires an olive colour, and is the *protoxide*. Exposed to moist air, it passes into the state of deutoxide and peroxide.[‖]

Deutoxide.

1073. When peroxide of manganese is heated red-hot till it ceases to give out gas, a dark reddish-brown *deutoxide* of manganese remains, which, when acted upon by sulphuric acid, is, according to Gay-Lussac, resolved into protoxide and peroxide. Exposed to moist air it absorbs oxygen, and is partly re-converted into peroxide. The deutoxide is most easily obtained pure, by triturating peroxide of manganese in fine powder, with superoxalate of potassa and water: a pink solution is obtained, from which ammonia throws down the deutoxide.[*]

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[*] Elements, p. 369.

[†] Traité de Chim. ii. 331.

[‡] For the results of several analysts, see Henry's Chemistry, Vol. ii. p. 3.

[§] On the separation of iron from manganese, see Quarterly Journal of Science and the Arts, Vol. vi. p. 153.

[‖] Dr Ure's method consists in dissolving common black manganese in sulphuric or nitric acid, adding a little sugar and precipitating by solution of potash. A white powder is obtained,[*] which being heated to redness out of the contact of air, becomes yellow, puce-coloured, and lastly red-brown. To be preserved, it should be washed in boiling water, previously freed from air, and then dried by distilling off the moisture in a retort filled with hydrogen. The dark olive oxide, when examined in large quantities, appears almost black; but when spread upon white paper, its olive tint is apparent. It takes fire when gently heated, increases in weight, and acquires a browner tint. It slowly absorbs oxygen from the air, even at common temperatures. It dissolves in acids without effervescence. The different tints which this oxide assumes by exposure to air are supposed by Sir H. Davy to depend on the formation of variable quantities of the black brown oxide, which probably retains the water contained in the white hydrate, and is hence deep puce-coloured. U. 572.

[*] The *hydrated protoxide*.

Peroxide.

1074. The *Peroxide of Manganese* is black; it is not soluble in acids; and abounds as a natural product.[†] It abounds in various parts of Europe and in the United States.[‡] It occurs compact and crystallized; the crystallized varieties have a grey metallic lustre. It is generally blended with sulphate of baryta.

Black wad.

Spontaneous inflammation of.

1075. The oxide of manganese which is sometimes called *black wad*, and which occurs in froth-like coatings on other minerals, is remarkable for its spontaneous inflammation with oil.—If half a pound of this be dried before a fire, and afterwards suffered to cool for about an hour, and it be then loosely mixed or kneaded with two ounces of linseed oil; the whole, in something more than half an hour, becomes gradually hot, and at length bursts into flame. U. 573.

Composition of the oxides.

1076. According to the analysis of Berzelius (*Annales de Chim.* lxxxvii.) the oxides of manganese are composed as follows:

	Protoxide.	Deutoxide.	Peroxide.
Manganese	100,	100,	100,
Oxygen	28,1	42,16	56,2

From which it appears that the proportions of oxygen to each other, are as 1, 1,5, and 28,1 : 100 : : 8 : 28,4, as the representative number of manganese. Dr Davy's analysis of the chloride of manganese[§] which was made in an unexceptionable way, gives the number 28,6. As further experimental evidence is wanting, we shall not be far from the truth in assuming 28,0 as the equivalent of manganese, and the three oxides will then consist of

	Protoxide.		Deutoxide.		Peroxide.
Manganese, 1 propor'l	28,0		28,0		28,0
Oxygen . . 1	8,	1,5 prop'l	12,	2 prop'l	16,
	36		40		44 B.[‖]

Chameleon mineral.

1077. Scheele having mixed black oxide of manganese with caustic potash, and exposed it to a heat sufficiently strong to melt the alkali, obtained a dark green, or blackish mass, which was soluble in water. By degrees, a yellow powder precipitates from the solution, and the liquid assumes a *blue* colour;

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[*] See also a memoir on the oxides and salts of manganese in the Annals of Philosophy (1821 Vol. i. N. S. p. 50.) Dr Forchhammer has there given other processes for obtaining the oxides of manganese.

[†] *Tritoxide* of Thomson.

[‡] For localities see Cleaveland's Mineralogy, 673.

[§] *Phil. Transactions*, 1812. 184. (1083.)

[‖] Dr Thomson from the composition of the sulphate makes the number for manganese 3,5 oxygen = 1 . . 28 Hydrogen = 1. *First Principles*, i. 367.

sometime after, the colour becomes *violet*, and then *red;* and finally black oxide of manganese precipitates, and the liquid loses all colour. In consequence of this curious succession of colours, the liquid thus obtained used to be distinguished by the name of *mineral chameleon.*

We may employ nitre instead of potash, and the process will succeed equally well.[*] The manganese and nitre, both reduced to powder, are mixed together, and thrown into a red-hot crucible, the nitric acid is decomposed, and we obtain a compound of highly oxidized manganese and potassa.[†] Its colour varies with the quantity of water added to it. A small quantity gives a green solution; a further addition changes it to blue; more still to purple, and a still larger quantity to a beautiful deep purple.

Exp.

Exp.

1078. The experiment may be varied, by putting equal quantities of this substance into two separate glass vessels, and pouring on the one hot, and on the other cold, water. The hot solution has a beautiful green colour, and the cold one is of a deep purple. The same material, with water of different temperatures, assumes various shades of colour. H. 2. 9.

1079. Messrs. Chevillot and Edwards have ascertained that the colour of the chameleon mineral is owing to manganese and not to any other metal; that the contact of oxygen gas with the fused materials is essential to its formation, during which oxygen is absorbed; and that the chameleon compound is a neutral salt, susceptible of assuming a regular crystallized form.[‡]

When these crystals are heated in contact with hydrogen gas, they cause it to inflame. They detonate violently with phosphorus; and set fire to sulphur, arsenic and antimony, and indeed to all combustible bodies hitherto tried.

Manganesic acid.

1080. Messrs Chevillot and Edwards conceive that in this compound the manganese is converted into *manganesic* acid, which combines with the potassa and forms a *manganesiate.* Forchhammer supposes that two acids exist, and that the different colours of the solution depend upon the conversion of *manganesous* into the *manganesic* acid.—Though it is extremely probable, that manganese is capable of forming one or more true acids with oxygen, yet the proportion of the elements of these acids may be considered as undetermined. H.

Manganese and Chlorine.

1081. *Manganese and Chlorine.*—By burning the metal in chlorine, or by exposing muriate of manganese to a strong heat, a pink semi-transparent flaky substance is obtained, which, when dissolved in water, produces a muriate of manganese.

Muriate.

1082. *Muriate of Manganese.* The action of muriatic acid on the black oxide of manganese is most important. According to the old theory, part of the acid acts on one portion of the oxide; and first reduces it to the state of protoxide, and then dissolves it, affording muriate of protoxide of manganese. The oxygen, thus liberated, uniting with another portion of muriatic acid, composes oxy-muriatic acid. But, on the more probable theory of chlorine, the hydrogen of the muriatic acid is attracted by the oxygen of the oxide, and the chlorine is not formed, but merely set at liberty.

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[*] Thomson's First Principles, 370.

[†] If caustic potash be used, the proportions should be one part of manganese and five or six of potash.

[‡] Ann. de Chim. et Phys. iv. 287 viii. 337.

how obtained.

1083. Muriate of manganese may be easily formed by heating excess of the black oxide with muriate of ammonia in a crucible dissolving the mass in water and filtering. If this solution be evaporated to dryness and fused out of the contact of air, the crystallized chloride is obtained.* Heated in contact of air, it is decomposed, and oxide of manganese remains. The crystals of muriate of manganese consist of

Protoxide of Manganese	38,50
Muriatic acid	20,04
Water	41,46
	100, H. 2. 8.

Nitrate.

1084. *Nitrate of Manganese.*—Dilute nitric acid readily dissolves protoxide of manganese, and forms a very soluble and difficultly crystallizable *proto-nitrate.* The same salt may be obtained by digesting peroxide of manganese in nitric acid with a portion of gum or sugar, which abstracts oxygen, carbonic acid is evolved, and the protoxide dissolved by the acid. Exposed to light, the solution of the protonitrate lets fall a portion of peroxide of manganese.

When dilute nitric acid is poured upon the deutoxide of manganese, a protonitrate and peroxide are formed.

The composition of nitrate of manganese, according to Prof. Brande is 36 protoxide + 54 acid = 90. According to Dr Thomson, it consists of 1 atom acid, 1 protoxide and 7 atoms water. *First. Prin.* ii. 349.

Manganese and Sulphur.

1085. *Manganese and Sulphur* appear unsusceptible of combination; but a compound of oxide of manganese and sulphur is found in Transylvania and Cornwall. It is of a blackish grey colour, and metallic lustre. The oxide, however, unites with sulphur by fusion, in the proportion of 8 of the former to 3 of the latter; and a compound is obtained of a green colour which gives out sulphuretted hydrogen gas by the action of acids. H.†

1086. *Sulphate of Manganese* is formed by dissolving the protoxide or protocarbonate in the acid, and evaporating to

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* According to Dr J. Davy the chloride consists of

Chlorine	54	100	117,64
Manganese . .	46	85	100
	100		

Now 54 : 46 : : 30 : 30,6. The weight, therefore, of the atom of manganese, deduced from the chloride, exceeds that inferred from the oxide. It is not improbable that 30 will prove to be very near the true number. H. ii. 6.

† *Hyposulphite of Manganese* remains in solution when sulphate of manganese is decomposed by hyposulphate of lime.

dryness: a white *protosulphate* is formed, which crystallizes in rhomboidal prisms, and consists of Sulphate.

36 protoxide + 40 sulphuric acid = 76.

It is very soluble in water, and has a bitter styptic taste: at a bright red heat it gives out oxygen, and sulphurous acid and deutoxide of manganese remain. It may also be obtained by mixing peroxide of manganese into a paste with sulphuric acid, and heating it in a basin nearly to redness: oxygen is evolved, and the dry mass washed with water affords the sulphate.

Deutosulphate.

1087. *Deutosulphate of Manganese* is formed by digesting he deutoxide in sulphuric acid diluted with its bulk of water: a red solution is formed, but the salt cannot be obtained in a neutral or separate state, for the application of heat evolves oxygen, and forms protosulphate. It is, probably, to a little deutosulphate that the occasional red tinge of the protosulphate is to be attributed.*

Carbonate.

1088. *Carbonate of Manganese* is white, insipid, and insoluble in water. It is precipitated by alkaline carbonates from the protomuriate or protosulphate, and consists of 36 protoxide + 22 carbonic acid = 58.†

Characteristics of the proto-salts of manganese.

1089. The salts of manganese containing the protoxide are mostly soluble in water, and the solution becomes turbid and brown by exposure to air. They are not precipitated by hydriodic acid; they furnish white precipitates with the alkalies, which soon become discoloured by exposure to air; they are precipitated white by ferro-prussiate of potassa, and yellow by hydrosulphuret of ammonia.

Uses.

1090. The native peroxide of manganese is used in the laboratory as a source of oxygen, and is largely employed in the preparation of chlorine, especially by the bleachers. It is used in glass-making, and, when added in excess, gives it a red or violet colour. It is also employed in porcelain painting; and it gives common earthen ware a black colour, by being mixed with the materials before they are formed into vessels.

SECTION IX. *Iron.*

1091. THE most important native combinations of iron, whence the immense supplies for the arts of life are drawn, are the oxides. Iron is also found combined with sulphur, and with several acids; it is so abundant that there are few fossils

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* *Phosphuret of Manganese* is of a blue white metallic lustre, and considerably inflammable. *Phosphite and Hypophosphite of Manganese* have not been examined. *Phosphate of Manganese* is precipitated in the form of a white insoluble powder, by adding phosphate of soda to muriate of manganese.

† According to Dr John it is composed of

Protoxide	55,84
Water	10,
Carbonic acid	34,16
	100,

free from it. It is also found in some animal and vegetable bodies, and in several mineral waters.

Iron is a metal of a blue white colour, fusible at a white heat. Its specific gravity is 7,78. It has not been so long known as many of the other metals; it was, however, employed in the time of Moses for cutting instruments. It is extremely ductile, but cannot be hammered out into very thin leaves.

Native. 1092. Iron is sometimes found native, and is usually regarded as of meteoric origin, for it is invariably alloyed by a portion of the metal nickel, and a similar alloy is found in *meteoric stones*. *Native Iron* is flexible, cellular, and often contains a green substance of a vitreous appearance. It has been found in Africa, in America. and in Siberia, where a mass of it weighing 1600 lbs was discovered by Professor Pallas. The mass found in Peru, described by Don Rubin de Celis, weighed 15 tons. Many masses are scattered over the continent of North America, for which see CLEAVELAND's *Mineralogy*, 583.

Combines with oxygen. 1093. *Iron and Oxygen.*—Exposed to heat and air iron quickly oxidizes, or in common language rusts. If the temperature of the metal be raised, this change goes on more rapidly, and when made intensely hot, takes place with the appearance of actual combustion. Thus the small fragments, which fly from a bar of iron during forging, undergo a vivid combustion in the atmosphere; and iron filings, projected upon the blaze of a torch, burn with considerable brilliancy. The oxide, obtained in these ways is of a black colour, and is still attracted by the magnet.

Effect of water, at common temperatures. 1094. By contact with water at the temperature of the atmosphere, iron becomes slowly oxidized, and hydrogen gas is evolved. It has been contended by Dr Marshall Hall (*Jour. Roy. Inst* vii. 55) that water, provided it be entirely deprived of oxygen gas, and secured from contact with atmospheric air, does not oxidate iron at common temperatures; but it has been shown by M. Guibourt (*Ann. de Chim. et Phys.* xi. 40) that this inaction of pure water on iron, takes place only when the quantity of metal relatively to the fluid is very small; and that a temperature of from 120° to 140° F. renders water decomposable by iron, especially when the metal bears a considerable proportion to the water.

Of steam. 1095. When the steam of water is brought into contact with red-hot iron, the iron is converted into the black oxide; and an immense quantity of hydrogen gas is set at liberty (351). The iron is found to have lost all its tenacity, and may be crumbled down into a black powder, to which the name of *finery cinder* was given by Dr Priestley. In composition it does not appear to differ from the oxide of iron obtained by the action of atmospheric air, and it is strongly magnetic. By a careful repetition of the process, Dr Thomson found, that 100 grains of iron, ignited in contact with the vapour of water, acquire 29,1 grains of oxygen.

1096. When iron is dissolved in diluted sulphuric acid, the acid is not decomposed; but the metal is oxidized at the expense of the water, and hydrogen gas is obtained in abundance. (328) Now as water is composed of two volumes of hydrogen and one of oxygen, a quantity of oxygen, equal in volume to half the hydrogen gas obtained, must have combined with the metal; that is, for every 200 cubic inches of hydrogen, oxygen equal to 100 cubic inches or 33,8 grains must have united with the metal. Dr Thomson, from an experiment of this kind, calculated that 100 grains of iron, after the action of dilute sulphuric acid, had gained 27,5 of oxygen. It is to be considered, however, that the purity of the iron employed will materially affect the result; for if the iron contain charcoal, as is almost always the case, carburetted hydrogen will be mixed with the hydrogen; and the hydrogen in this gas being in a condensed state, the apparent will be less than the real quantity of hydrogen disengaged. Of dilute sulphuric acid.

Iron, by all the different processes which have been described, is converted into an oxide of a black colour, having the same proportions of oxygen and metal, and still retaining the magnetic property. H. 2. 18.

1097. The *protoxide of iron* may be procured by precipitating a solution of sulphate of iron by potassa, washing the precipitate out of the contact of air, and drying it at a red heat. It is black, and consists of 28 iron + 8 oxygen = 36. It is supposed by M. Gay-Lussac, that in drying, an additional proportion of oxygen is always absorbed, and that the black oxide is a deutoxide composed of 100 metal + 37,8 oxygen: (*Ann. de Chim. et Phys.* Tom. i.) but there is some reason to doubt the accuracy of this conclusion. Protoxide.

The recently precipitated protoxide of iron is sparingly soluble in ammonia, and in carbonated alkalies.

Black protoxide of iron may also be obtained by burning iron in oxygen gas; this very beautiful experiment was devised by Dr Ingenhouz, and is best performed by attaching a straight piece of watch spring, wound round with harpsichord wire, to the stopper of an air-jar of oxygen gas (262): as the wire burns, it drops in black gobules of oxide into the water beneath.

This oxide of iron used to be prepared for pharmaceutical use, by moistening iron filings with a small quantity of water, and exposing them to the air for a day or two; a quantity of black oxide thus forms, which is separated by washing, and the process repeated till the whole of the metal is thus oxidized. It was called *martial ethiops*. It is black, tasteless, and insoluble in water.

1098. When protoxide of iron is boiled in nitric acid, and precipitated by ammonia, washed, and dried at a low red heat, it increases in weight and acquires a brown colour. This is the *peroxide*[*] composed of 28 iron + 12 oxygen = 40. It may be also obtained by igniting green vitriol (1114); and was formerly known by the name of *crocus martis*, or *Saffron of Mars*, and *colcothar*.

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[*] *Tritoxide* of Thenard, ii. 341, edit. 4.

Equivalent number for iron.

1099. The equivalent number for iron is founded on the presumption that it exists as a protoxide in the sulphate: now 100 grains of pure iron, during solution in sulphuric acid, evolve 170 cubic inches of hydrogen at mean temperature and pressure; and consequently 85 cubic inches of oxygen = 28,73 grs have been transferred to the iron: and 28,73 : 100 : : 8 : 27,8. The quantity of oxygen in the peroxide of iron is shown to be to that in the protoxide as 3 to 2 by the following experiment. 100 grains of iron were dissolved in nitric acid and the solution evaporated to dryness, and the residue sufficiently heated to drive off the whole of the acid: 143 grains of peroxide remained. So that the composition of these oxides stands thus:

	Protoxide.	Peroxide.
Iron . .	100 . . .	100
Oxygen .	28,73 . . .	43
	128,73	143

And 28,73 : 43 : : 8 : 12 = 1½ proportional of oxygen.

M. Gay-Lussac (*Ann. de Chim. et Phys* i. and *Ann. de Chim.* lxxx.) has detailed some experiments, which he considers as demonstrating the existence of a third definite oxide of iron, intermediate between the above oxides, and composed of iron 100 + oxygen 37,8. Such a compound he thinks is obtained by passing steam for a length of time over red-hot iron: it seems, however very questionable whether this be a definite compound: it is rejected by Berzelius, who only admits the oxides above described.

M. Thenard, in describing the oxides of iron, (*Traité* ii. *Edit.* 4. 339) considers the octoëdral and magnetic iron ores as composed of this deuotoxide, and does not allow of the existence of native protoxide of iron. In the present state of the question, however, I should feel rather inclined to view this deutoxide as a mixture of the protoxide and peroxide, than as any definite compound, more especially as the analyses of the native magnetic oxides give variable proportions of oxygen. B.

In order that the representative number of iron may also be its equivalent number, it is represented by 28. But the peroxide, instead of consisting of 1 proportional metal + 2 oxygen, consists of 1 proportional metal + 1,5 oxygen; and the chloride and perchloride bear the same relation to each other. The case however is different with the sulphurets; for the sulphuret consists of 1 proportional iron + 1 sulphur: and the bi-sulphuret of 1 iron + 2 sulphur.

M. Gay-Lussac has shown the curious fact, that although red-hot iron decomposes water, hydrogen is capable of decomposing all the oxides of iron at a red heat.—*Ann. de Chim. et Phys.* i. 37.

1100. The *Native Oxides of Iron* constitute a very extensive and important class of metallic ores. They vary in colour, depending upon mere texture in some cases; in others, upon the degree of oxydizement. Some varieties are magnetic, and those which contain least oxygen are attracted by the magnet. The most important are *Magnetic Iron Ore*, which occurs massive, and crystallized in octoëdra. Its specific gravity is 4,5. It is often sufficiently magnetic to take up a needle. It occurs chiefly in primitive countries, and is very abundant at Roslagen in Sweden, where it is manufactured into a bar-iron particularly esteemed for making steel. Native Oxides.

Another variety of oxide of iron is called *iron glance*, and *micaceous iron ore*. It is found in the isle of Elba; and among volcanic products. A third variety is *Hæmatite*, or red iron-stone; it occurs in globular and stalactitic masses, having a fibrous and diverging structure. Most of the British iron-plate, and wire, is made from it.

A fourth variety of oxide of iron is known under the term of *clay iron-stone*, on account of the quantity of argillaceous earth with which it is contaminated. Though this is far from the purest iron ore found in Great Britain, it is the chief source of the cast and bar-iron, in ordinary use. Its employment is chiefly referable to the coal which accompanies it.

The essential part of the process by which these ores of iron are reduced, consists in decomposing them by the action of charcoal at high temperatures. The argillaceous iron of Wales, Shropshire, &c. is first roasted, and then smelted with lime-stone and coke: the use of the former being to produce a fusible compound with the clay of the ore, by which the latter is enabled to act upon the oxide, and to reduce it to the metallic state.

1101. The two oxides of iron form distinct salts with the acids.

The salts containing the black oxide are of a green colour, mostly crystallizable, become reddish brown by exposure to air, and their solutions absorb nitric oxide gas and become of a deep olive colour. The salts with the brown oxide do not, with very few exceptions, crystallize: they are brown, soluble in alcohol, and do not absorb nitric oxide. Salts of iron.

The alkalies precipitate hydrated oxides from these solutions.

1102. *Iron and Chlorine* unite in two proportions; the *chloride* may be obtained by evaporating *protomuriate of iron* to dryness, and exposing the residuum to a red heat, out of the contact of air. A grey brittle lamellar substance is formed, which when analyzed by Dr Davy, was found to consist of Chloride.

Chlorine	53,2	100	113,63
Iron	46,8	88	100.
	100.		

Composition

In this case the results of analysis do not agree with theory, for if constituted of 1 atom of chlorine = 36 + 1 atom of iron = 28, its composition ought to be

Chlorine	56,3	100	128,85
Iron	43,7	77,6	100
	100.	H. 2. 21.	

Perchloride. 1103. When iron wire is heated in chlorine, it burns with a red light, and produces a compound which rises in beautiful brown scales. It is the *perchloride of iron*. It consists of

Chlorine	66,1	100	194,174
Iron	33,9	51,5	100.
	100.		

In this case we have also the apparent anomaly of an atom and a half of chlorine being united with an atom of iron, for 100 : 51,5 : : $36 \times 1\frac{1}{2} = 54,28$. H. 2. 22. This, and similar anomalies, are best reconciled, Dr Henry conceives by multiplying by 2 the numbers expressing the proportions, which will make the ratio as 2 to 3, instead of as 1 to $1\frac{1}{2}$.* The chloride and perchloride of iron produce *protomuriate, and permuriate* of iron when acted upon by water.

Muriates. 1104. *Muriate of Iron.* Muriatic acid dissolves iron and its oxides with great ease; and affords two distinct salts, differing from each other according to the state of oxidation of the metal. The muriate containing the black, or protoxide, is green, and that containing the oxide at the maximum, or peroxide, red.

Protomuriate. 1105. The green or *protomuriate of Iron* is best obtained by digesting black sulphuret of iron in dilute muriatic acid; sulphuretted hydrogen is evolved, and a green solution obtained, which, filtered and evaporated, yields pale green crystals, very soluble, and of a styptic taste. This salt abundantly absorbs nitric oxide gas; the solution is of a very deep brown colour; when heated, red oxide of iron falls and a portion of ammonia is formed; a great part of the gas at the same time escapes.

This salt may also be obtained by dissolving iron filings in muriatic acid excluded from air; but the above process is preferable, as the sulphuretted hydrogen prevents any part of the iron passing into the state of permuriate.

Permuriate. 1106. *Permuriate of Iron* is formed by digesting the peroxide in muriatic acid: it dissolves without the evolution of chlorine, and when evaporated to dryness, furnishes a reddish brown deliquescent mass of a very astringent taste, soluble both in water and alcohol. It forms the basis of the *tinctura muriatis ferri* of the ***Pharmacopœia***. Permuriate of iron is also formed by exposing the protomuriate to air.

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* That the chlorine in the protochloride of iron is to that in the perchloride as 1 to 1,5, is shown by Dr Davy in his valuable paper on the chlorides, (*Phil. Trans.* 1812, 169.) and the equivalent number of iron, as deduced from his analysis is somewhat above 28. It must be confessed that the anomaly in the oxides and chlorides of iron throws some difficulty in the way of applying to them their equivalent numbers, but as the foundations of chemistry are purely experimental, we must not endeavour to do away that difficulty by a theoretical substitute. There is a difference in the relations of iron to oxygen and chlorine, compared with its relations to sulphur, which does not exist elsewhere; of the cause of this difference we are at present ignorant. B.

Exp.

Berzelius describes a striking experiment founded on this property. If a solution of the green muriate be exposed to the atmosphere, in a tall cylindrical glass jar, for some days, and a few drops of pure ammonia be then introduced at different depths, by means of a tube, the precipitate formed near the surface will be green, a little lower blue; still lower greyish; then of a dirty white; and at the bottom perfectly white, provided time has not been allowed for the atmospheric oxygen to penetrate so low. H. 2. 25.

1107. When permuriate of iron is exposed to heat, muriatic acid, chlorine, and water are evolved, chloride of iron sublimes, and a portion of peroxide remains in the retort.

1108. When muriate of ammonia and peroxide of iron are mixed and exposed to heat in a proper subliming vessel, a yellow sublimate is obtained, which is the *ens veneris* and *flores martiales* of old pharmacy: the *ammoniæ et ferri murias* of the ***Pharmacopœia;*** it consists chiefly of muriate of ammonia, with a small but variable proportion of per-muriate of iron.[*]

Nitrate.

1109. *Nitrate of Iron.* The *nitric acid* dissolves the protoxide and peroxide of iron, and produces a green *proto-nitrate* and a red pernitrate. In its concentrated state the acid scarcely acts upon iron, but, when diluted with a small quantity of water, it dissolves iron with great vehemence; and with the extrication of a large quantity of impure nitrous gas.[†] H. A solution is formed of a reddish brown colour containing *per-nitrate* of iron, and affording a brown precipitate to the alkalies.

If the nitric acid be considerably diluted, (sp. gr. 1,16) the action is slow and very little gas escapes; the solution acquires an olive brown colour from the nitric oxide which it contains, but exposed to the air it becomes pale green, in consequence of the escape of that gas. The alkalies produce a green precipitate in this solution: it cannot be obtained in crystals by the usual process, and passes into pernitrate by exposure to air.

Method of obtaining in the large way.

1110. To obtain nitrate of iron, in which the oxide is at the minimum, acid of the specific gravity of 1,25, or even less, must be used; the iron must be added in large pieces, and at distant intervals, and the operation carried on without the access of air. When this solution is made on a large scale for the purposes of the dyer, it is proper to connect the vessel in which it is prepared, with a large receiver; for in the latter, a quantity of nitrous acid will be found, which is worth the trouble of collecting. H. 2. 24.

Sulphuret.

1111. *Sulphur and Iron.* Iron combines with sulphur, and affords compounds, the characters of which vary greatly according to the proportions of their components. (*a*) A paste of iron filings, sulphur and water, if in sufficient quantity, will burst, after some time, into a flame. (*b*) A mixture of one part of iron filings and three parts of sulphur, accurately mixed, and melted in a glass tube, at the moment of union, exhibits a brilliant combustion. The best method, however, of effecting the combination of iron and sulphur is to take a bar of the metal, while of a glowing heat, from a smith's forge, and to rub it with a roll of sulphur. *The compound of iron and sulphur falls down in drops, and may be preserved in a phial. Of the compounds of sulphur, this is one of those which are best adapted for affording pure sulphuretted hydrogen gas with diluted acids. (*c*) The sulphuret of iron, when moistened, rapidly decomposes oxygen gas, and passes to the state of sulphate. (*d*) When diluted sulphuric or muriatic acid is poured on it, we obtain sulphuretted hydrogen gas.

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[*] *Iodine and Iron* readily form a brown compound, fusible at a red heat, and which, when acted on by water, forms a *hydriodate* of a green colour.

[†] A mixture of nitrous and nitric oxides.

In the sulphuret, made artificially by fusion, as well as in the native sulphuret, iron (it has been shown by Proust and Mr Hatchett) is in the metallic state. Two compounds of iron and sulphur have been proved to exist, the one with a smaller, the other with a larger proportion of sulphur. The former, which is distinguished by the property of being magnetic, is the *proto-sulphuret*. The *bi-sulphuret* is known only as a natural product; it is not magnetic, is nearly insoluble in diluted sulphuric and muriatic acids; and gives no sulphuretted hydrogen gas with acids. But the proto-sulphuret is readily soluble in dilute acids, and gives during solution abundance of sulphuretted hydrogen. It is composed of 28 iron + 16 sulphur; and the yellow, or bi-sulphuret, of 28 iron + 32 sulphur.

Iron pyrites.

1112. The natural sulphurets of iron are called *iron pyrites*, and Mr Hatchett has shown that the *magnetic pyrites* contains just half the proportion of sulphur existing in the *common pyrites*. (*Phil. Trans.* 1804.)

Use.

The principal use of pyrites is in the formation of *green vitriol*, for which purpose the ore is gently roasted and exposed to air and moisture. Some varieties are spontaneously decomposed, and furnish this salt. Pyrites has also lately been used in the production of sulphuric acid. (543)

Sulphate.

1113. *Sulphate of Iron.* When diluted sulphuric acid is made to act upon iron, we obtain a compound of that acid with the protoxide, a *protosulphate of iron*. The solution yields crystals, which have a beautiful green colour, and the shape of oblique rhombic prisms, not of rhomboids as is sometimes represented.† They have a styptic taste, and are soluble in about 2 of cold parts and $\frac{3}{4}$ths their weight of boiling water, but insoluble in alcohol.

1114. This salt is called *copperas* or *green vitriol*, and is often prepared by exposing roasted pyrites to moisture, in which case it is impure. It is usually formed by dissolving iron filings or turnings, in dilute sulphuric acid, filtering and evaporating the solution, and setting it aside to crystallize. It is also obtained, perfectly free from persulphate, by acting upon sulphuret of iron by dilute sulphuric acid. It consists of one proportional of protoxide = 36 + 1 proportional of acid = 40, and in its crystallized state contains seven proportionals of water = 63. Its solution absorbs nitric oxide gas, and acquires a deep brown colour; it also absorbs chlorine, muriatic acid is formed, and the iron becomes peroxidized so that water is here decomposed.

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* See Amer. Jour. of Science, viii. 104.

† Annals of Philos. xi. 264.

Absorbs oxygen by exposure to air.

1115. Exposed to air and moisture, the protosulphate of iron gradually absorbs oxygen, and is partly converted into a persulphate. It may also be converted into persulphate by nitric acid. When heated, it fuses in its water of crystallization, and at a high temperature evolves a mixture of sulphurous and sulphuric acids, peroxide of iron remaining in the vessel: by this process sulphuric acid used formerly to be prepared, and the residue was known under the name of *caput mortuum vitrioli* or *colcothar*. If the green crystals of this salt be exposed to a temperature of about 300°, they lose a portion of water, and crumble down into a white powder.

Native.

1116. *Native Green Vitriol* is frequently found associated with iron pyrites, being produced by its decomposition: it occurs in some coal mines.

Persulphate

1117. *Persulphate of Iron* is obtained by dissolving the moist red oxide in dilute sulphuric acid; it does not crystallize, but affords, by evaporation, a brown deliquescent mass, consisting of 1 proportional of peroxide + 1,5 sulphuric acid, or 40 oxide + 60 sulphuric acid. It is formed in the mother waters of the sulphate. Its taste is highly astringent, and when dry it becomes white: if in this state it be digested in hot sulphuric acid, or if peroxide of iron, recently precipitated from the pernitrate, be boiled with excess of sulphuric acid, the solution yields octoëdral crystals nearly white, and of a sweetish styptic taste: these are probably a *bi-persulphate of iron*.*

Phosphuret.

1118. *Phosphuret of Iron* may be formed by dropping phosphorus into a crucible containing red-hot iron wire; it is a brittle grey compound, and acts upon the magnet. Upon the subject of the magnetic qualities of the sulphuret and phosphuret of iron, the reader is referred to Mr Hatchett's analysis of the magnetic pyrites. (*Phil. Trans.* 1804.)

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* When a solution of proto-sulphate of iron is heated with access of air, part of the protoxide passes to the state of peroxide, and combining with a portion of acid, falls down in the form of a yellow powder, which, according to Berzelius, is a sulphate of the peroxide with *excess of base*, or a *sub-sulphate*. The proportions of its components are

		Atoms.	
Sulphuric acid	15,5	1	= 40
Peroxide of iron	63,	4	= 160
Water	21,5	6	= 54
	100,		254

Other sulphates with base of peroxide of iron (called from the atomic proportions of their constituents *per-bisulphate*, and *per-quadrisulphate*), have been investigated by Dr Thomson and others. (*Ann Philos.* x. 102. xiii. 466 and 298.); but no sulphate of protoxide with *excess of acid* is yet known. H. 2. 23.

Phosphates. 1119. *Phosphates of Iron.* These are both insoluble, and may be formed by adding solution of phosphate of soda, to protosulphate and persulphate of iron. The *protophosphate* of iron is of a pale blue colour; the *perphosphate* is white. Both have been analyzed by Vogel; but his results do not coincide strictly with any atomic proportions.[*]

Native. 1120. *Native Protophosphate of Iron* occurs in the form of a blue earthy powder, and also in prismatic crystals.[†] The former has sometimes improperly been termed *Native Prussian Blue*, and has been found in alluvial soil: the latter occurs with iron pyrites in Cornwall.

Carburet. 1121. *Iron and Carbon.* Iron combines with carbon in various proportions; and the varieties of proportion occasion great differences of properties in the compounds. On these varieties, and the occasional combination of a small proportion of oxygen, depend the qualities of the different kinds of iron used in the arts, as cast-iron, steel, &c. &c.

Plumbago. 1122. The substance termed *Plumbago, Graphite*, or *Black Lead*, is generally regarded as a true *carburet of iron:* this is not an uncommon mineral, though rarely found of sufficient purity for the manufacture of pencils:[‡] the coarser kinds and the dust, are melted with sulphur to form common carpenters' pencils: crucibles are sometimes made of it, and it forms an ingredient in compositions for covering cast-iron, and for diminishing friction in machines. According to Messrs Allen and Pepys it consists of

$$95 \text{ carbon} + 5 \text{ iron} = 100.$$

It may here be observed that considerable difficulty attends the accurate analysis of compounds of carbon and iron, in estimating the proportion of the former: this has generally been indirectly effected by ascertaining the quantity of iron, and considering the loss of weight as carbon, a method obviously objectionable. If the action of dilute sulphuric acid be resorted to, a portion of carbon is carried off by hydrogen; the same is the case with muriatic acid; and if nitric acid be used, some carbonic acid may be formed, and artificial tannin is produced.

Fusion of Plumbago. Plumbago burns with great difficulty: its composition was ascertained by the above-mentioned chemists, by exposing it in the apparatus used for burning the diamond, to a current of oxygen at a red heat, and ascertaining the quantity of carbonic acid and of oxide of iron thus produced.[||] It has been fused by Professor Silliman by means of Dr Hare's Deflagrator; the fused portions presenting various shades of white, brown, amber and topaz colours. Some of the white globules obtained in these experiments, were perfectly limpid and could not be distinguished by the eye, from portions of diamond; other globules resembled calcedony. Similar results were obtained by means of the compound blow-pipe. (See *American Journal,* vi. 344, &c.)

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[*] Ann. Philos. xiii. 310.

[†] See Cleaveland's Mineralogy, 613.

[‡] See a description of the mine at Borrodale. *Boston Jour. of Philos.* ii. 332.

[||] An ingenious mode of analysis employed by Mr Mushet, consists in ascertaining the quantity of litharge which a given quantity of the iron under examination is capable of reducing to a metallic state.

Protocarbonate.

1123. Carbonic acid may be combined with the protoxide of iron, by adding carbonate of potassa to sulphate of iron; a green precipitate of *protocarbonate of iron* falls, which exposed to air, becomes brown, and evolves carbonic acid. Solution of bi-carbonate of potassa occasions a white precipitate with sulphate of iron, part of which is re-dissolved on adding excess of the carbonated alkali.

Prussian blue.

1124. When hydrocyanate of potassa is added to the solutions of salts of iron, it occasions a bluish white precipitate in those containing the protoxide, and a blue precipitate in those containing the peroxide. The former precipitate is probably a ferrocyanate of iron, containing the protoxide; the latter, a ferrocyanate containing the peroxide, and which has been long known under the name of *Prussian Blue.*

Process for preparing.

1125. Prussian blue is usually prepared by the following process:—Equal parts of subcarbonate of potassa and some animal substance, such as dried blood, or horn shavings, are heated red hot, in a crucible, and six or eight parts of water are poured upon the mixture when it has quite cooled. The solution is filtered, and found to contain *hydrocyanate of potassa,* along with carbonate of potassa, and some other products. It is mixed with a solution containing two parts of alum and one of sulphate of iron; a precipitate falls, at first of a dingy green hue, but which, by copious washings with very dilute muriatic acid, acquires a fine blue tint, and is called *Prussian Blue,* having been discovered by Diesbach, a colour-maker of Berlin, in 1710. The first description of the mode of preparing it is given by Woodward in the *Phil. Trans.* for 1724.

Theory.

1126. In this process the animal matter is decomposed, and resolved into a variety of products arising from the reunion of its ultimate component parts. The matter remaining in the crucible contains cyanuret of potassium, and when acted upon by water, hydrocyanate of potassa, with a little carbonic acid and ammonia, is formed in consequence of the decomposition of a portion of the water; and consequently the principal salts contained in the washings of the black matter remaining in the crucible are carbonate and hydrocyanate of potassa, which, when added to a solution of sulphate of iron, form a precipitate of oxide and ferrocyanate of iron; the former is removed by the dilute muriatic acid. The aluminous earth of the alum gives a *body* to the precipitate, which improves it as a pigment.

The above seems to be the simplest view of the formation and composition of Prussian blue; a variety of other opinions respecting its nature have been entertained, but they require further experimental verification.* B.

Method of preparing it for chemical purposes.

1127. The prussian blue of commerce is an impure substance, and contains a variety of other matters, especially a quantity of alumina. For chemical experiments, it is proper, therefore, to prepare it by mixing the solutions of ferrocyanate of potassa and persulphate or permuriate of iron, and washing the precipitate, first with muriatic acid, and then with water. If a salt of iron be used, containing an oxide at the minimum of oxidation, the precipitate produced by ferrocyanate of potassa is white, and continues so as long as it is guarded from the action of the atmosphere; but it changes to blue by exposure to the air, or by mixture with any agent capable of imparting oxygen. Potassa is always found as an ingredient of the white prussiate.

Properties.

1128. Prussian blue is insoluble in water, and in acids,† unless when they are concentrated and heated. When thoroughly dried, it shows a great affinity for moisture, by absorbing it rapidly from the atmosphere. It is not decomposed by being heated to 307° F.; but, at a higher temperature, it catches fire and burns in the manner of tinder, leaving from 54 to 60 per per cent. of oxide of iron.

Prussian blue submitted to distillation *per se* gives water, hydrocyanate of ammonia, carbonic acid, and other gases.‡ H. 2. 27.

Ferrocyanate of potassa.

1129. When Prussian blue is boiled with potassa it is decomposed; it loses its blue colour, oxide of iron is separated, and on filtering and evaporating the solution, a triple salt is obtained, consisting of hydrocyanic acid, potassa, and oxide of iron; this has been called *triple prussiate of potassa*, and *ferrocyanate of potassa*. It is best formed by adding powdered Prussian blue, previously heated with a dilute sulphuric acid composed of one part of acid and five of water, and afterwards washed, to a hot solution of potassa, as long as its colour is destroyed. This salt forms permanent yellow cubic and tabular crystals, more soluble in hot than cold water, insoluble in alcohol, and of a peculiar taste. Boiled with dilute sulphuric or muriatic acids, hydrocyanic acid is given out, and a precipitate formed similar to that which the salt produces in a solution of proto-sulphate of iron. It is decomposed in a retort at a red heat, hydrocyanic acid and ammonia are evolved, and the residue consists of charcoal, potassa, and iron.

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* According to Mr Porrett's view, it is a compound of ferrocyanic acid with peroxide of iron. Berzelius not admitting the existence of any such acid as the ferrocyanic, regards Prussian blue as a compound of hydrocyanate of protoxide with peroxide of iron, in proportions admitting of some variation. (*Ann. Philos.* N. S. i. 444.) Robiquet, on the other hand, considers it as a cyanide of iron, combined with a ferrocyanate of the peroxide and with water. (*Ann. de Chim. et Phys.* xii. and vii.) H. 2. 26.

† It is not acted upon by dilute nitric, sulphuric or muriatic acids, which renders it extremely improbable that it should be a hydrocyanate of iron, and strengthens the opinion of Mr Porrett, that it is a *ferrocyanate*, or a compound of peroxide of iron with the peculiar acid mentioned at 1130 and containing hydrogen, oxygen, iron, and cyanogen. (*Brande.*)

‡ Besides Prussian blue, there appears from Berzelius' experiments (*Ann. of Philos.* N. S. i. 444) to be another blue compound of the same elements, which is soluble to some extent in water. Prussian blue, in the dingy green state in which it is first precipitated seems also to contain an excess of base, which muriatic acid removes. There are probably therefore, three compounds in which the peroxide, and one in which the protoxide, exists as base. H.

Ferrochyazic acid of Porrett.

1130. Mr Porrett (*Phil. Trans.* 1814.) considers the ferrocyanates as compounds of the respective bases, with an acid consisting of the elements of the hydrocyanic acid united to the protoxide of iron. This acid he terms *ferrochyazic acid*, derived from the initial letters of carbon, hydrogen and azote. He obtained this acid dissolved in water, by adding to a solution of ferrocyanate of baryta just sulphuric acid enough to precipitate the baryta. It has a pale yellow colour, no smell, and is decomposed by a gentle heat or strong light, in which case hydrocyanic acid is formed, and white hydrocyanate of iron is deposited, which becomes blue by exposure. Gay-Lussac, observing the production of the ferrocyanate of potassa by adding protoxide of iron to hydrocyanate of potassa, supposes that a portion of the hydrocyanic acid is decomposed by the oxide, giving rise to a compound of cyanuret of iron with hydrocyanate of potassa.

Gives precipitates with metallic solutions.

1131. When solution of ferrocyanate of potassa is added to metallic solutions, precipitates are obtained which have different colours; (See TABLES), and which appear to be ferrocyanates, for when treated with solution of potassa, a ferrocyanate of potassa is obtained.*

1132. The *ferrocyanates* of *ammonia*, *soda*, *lime*, *magnesia*, *baryta* and *strontia*, may be obtained by boiling those alkalies and earths with Prussian blue.†

1133. The salts of iron are mostly soluble in water and the solution is reddish brown, or becomes so by exposure to air. It affords a blue precipitate with ferrocyanate of potassa; and a black precipitate with hydrosulphuret of ammonia. Infusion of gall-nuts produces a black or deep purple precipitate. The hydriodic acid occasions no change.

Alloys.

1134. Of the alloys of iron, *tin-plate* is the only one of consequence. It is made by dipping clean iron plates into melted tin. The process is described at length by Mr Parkes. (*Boston Jour. of Philos.* ii. 243.) When tin-plate is washed over with a weak acid, the crystalline texture of the tin becomes beautifully evident, forming an appearance which has been called *moiré metallique.*—*Quarterly Jour. of Science*, Vol. v. 368.

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* The ferrocyanate of potassa has been analyzed by Berzelius, who decomposed it by heating it with peroxide of copper, and obtained carbonic acid and azotic gases, in the proportions in which they are evolved by the decomposition of cyanogen, viz. 2 volumes of the former and one of the latter. Hence he considers it as a cyanide, and not a prussiate, and deduces its composition to be two atoms of cyanide of potassium + 1 atom of cyanide of iron. According to Mr Porrett its composition is

		Atoms.			Atoms.
Potassa	40,34	1	Azote	11,75	1
Iron	11,76	$\frac{1}{2}$	Hydrogen	,84	1
Carbon	20,17	4	Water	15,13	2

—forming 1 atom of ferrocyanic acid. H. 1. 534.

† *Borate of Iron* has a yellow colour and is insoluble; it is formed by adding borate of soda to sulphate of iron.

1135. An extremely important part of the chemical history of iron relates to the varieties of the metal which are found in commerce. These are much too numerous to be dwelt upon here; so that we shall limit our observations to the principal of them only, which are *cast iron, wrought iron* and *steel.*

Cast iron.

Of cast iron there are two principal varieties, distinguished by the terms *white* and *grey*. The first is very hard and brittle, and when broken, of a radiated texture. Acids act upon it but slowly, and exhibit a texture composed of a congeries of plates, aggregated in various positions.—Daniell, *Quarterly Journal of Science and Arts*, Vol. ii. 280.

Grey or mottled iron is softer and less brittle; it may be bored, and turned in the lathe. When immersed in dilute muriatic acid, it affords a large quantity of black insoluble matter, which Mr Daniell considers as a triple compound of carbon, iron, and silicium, and which has some very singular properties. The texture of the metal resembles bundles of minute needles.

Process of puddling.

1136. Cast iron is converted into wrought iron by a curious process, called *puddling*. The cast iron is put into a reverberatory furnace, and when in fusion is stirred, so that every part may be exposed to the air and flame. After a time the mass heaves, emits a blue flame, and gradually grows tough and becomes less fusible, and at length congeals. In that state it is passed successively between rollers, by which a large quantity of extraneous matter is squeezed out, and the bars are now malleable. They are cut into pieces, placed in parcels in a very hot reverberatory furnace, and again hammered and rolled out into bars. They are thus rendered more tough, flexible and malleable, but much less fusible, and may be considered as nearly pure iron.

Analysis shows that cast iron contains oxygen, carbon, often sulphur and phosphorus, either silica or silicium, and it appears very probable that calcium exists in some of the varieties.

By the process of puddling and rolling, these substances are burned away or squeezed out, and thus malleability is conferred upon the metal by rendering it more pure. A specimen of cast iron analyzed by Berzelius afforded iron 91,53—manganese 4,57—carbon 3,90.

Structure of wrought iron.

A bar of wrought iron, when its texture is examined in the mode pointed out by Mr Daniell, presents a fasciculated appearance, the fibres running in a parallel and unbroken course throughout its length. This structure may be well seen by tearing a bar of wrought iron asunder.

Steel.

1137. Steel is a compound of iron with carbon, the proportions being variable. It combines the fusibility of cast with the malleability of bar iron, and when heated and suddenly cooled it becomes very hard, whence its superiority for the manufacture of cutting instruments. If kept for a long time in fusion, it loses carbon and becomes pure iron.

Iron is converted into steel by a process called *cementation*, which consists in heating bars of the purest iron in contact with charcoal: It absorbs carbon and increases in weight, at the same time acquiring a *blistered* surface. This, when drawn down into smaller bars and beaten, forms *tilted steel;* and this broken up, heated, welded, and again drawn out into bars, forms *shear steel. English cast steel* is prepared by fusing blistered steel with a flux composed of carbonaceous and vitrifiable ingredients, casting it into ingots, and afterwards, by gentle heating and carefully hammering, giving it the form of bars. Cementation.

1138. Messrs Stodart and Faraday found, that by intensely heating pure steel with charcoal powder, a *carburet of iron*, of a dark grey colour, very brittle and highly crystalline was formed, which afforded upon analysis

$$94{,}36 \text{ iron} + 5{,}64 \text{ carbon} = 100.$$

In this compound, which was frequently made and afforded the same results on analysis, and which therefore may be regarded as definite, the proportion of carbon very far exceeds that in steel, so that the latter is probably a compound of pure iron with a variable proportion of the true carburet.

1139. The following table, drawn up by Mr Mushet, shows the quantities of charcoal which disappeared during the conversion of iron into the different *subcarburets of iron* known in commerce.—*Phil. Mag*. xiii.

Charcoal absorbed.		RESULTS.
$\frac{1}{120}$	. . . . . .	soft cast steel,
$\frac{1}{100}$	. . . . . .	common cast steel,
$\frac{1}{90}$	. . . . . .	the same, but harder,
$\frac{1}{50}$	. . . . . .	the same: too hard for drawing,
$\frac{1}{25}$	. . . . . .	white cast iron,
$\frac{1}{20}$	. . . . . .	mottled cast iron,
$\frac{1}{50}$	. . . . . .	black cast iron.

When the carbon amounts to $\frac{1}{50}$ of the whole mass, the hardness is at a maximum.

1140. Wootz. *Wootz* or *Indian steel* is truly valuable for the purpose of making edge tools. Its peculiar excellence is owing to combination with a minute portion of the earths alumina and silica: or rather, perhaps, with the bases of these earths. (*Quarterly Journal of Science*, vii. 288.) Whether the earths are found in the ore, or are furnished by the crucible used in making the steel, is not certainly known; nor is the Indian steelmaker probably aware of their presence. Wootz, in the state in which it is imported, is not fit to make into fine cutlery. It requires a second fusion, by which the whole mass is purified and equalized, and fitted for forming the finest edged instruments.

1141. Texture. The texture of steel, as exhibited by the action of an acid, is not fibrous, but appears somewhat lamellated.

Tempering.

1142. When steel is heated to a cherry-red colour, and then plunged into cold water, it becomes so extremely hard and brittle, as to be unfit for almost any practical purpose. To reduce it from this extreme hardness, is called by the workmen *tempering*, and is effected by again heating the steel to a certain point. The surface being a little brightened exhibits, when heated, various colours which constantly change as the temperature is increased, and by these colours it has been customary to judge of the temper of the steel.

A more accurate as well as convenient method is to use a bath and thermometer; the bath may be of mercury, or of the fusible mixture of lead, tin, and bismuth, or, indeed, of any fluid whose boiling point is not much under 600°. Into this bath the articles to be tempered are put, together with the bulb of a thermometer graduated to near the boiling point of mercury. The corresponding degrees at which the various colours appear, are from 430° to 600°. The first change is at about 430°, but this is too faint to be distinguished, except by comparison with another piece of untempered polished steel. At 460° the colour is straw, becoming deeper as the temperature is increased; at 500° the colour is brown; this is followed by a red tinge with streaks of purple, then purple, and at nearly 600° it is blue.

The degrees at which the respective colours are produced being thus known, it follows that the workman has only to heat the bath, with its contents up to the required point. For example, suppose the blade of a penknife (or one hundred of them) to require tempering: they are suffered to remain in the bath until the mercury in the thermometer rises to 460°, and no longer, that being the heat at which the knife (supposing it to be made of the best English cast steel) will be sufficiently tempered.

The advantages attending this method are obvious: the heat is equally applied to the whole; and the workman, instead of attending to the colour of each blade, has only to observe the thermometer.

1143. Some recent experiments, proving that steel, for certain uses, is sufficiently tempered long before it is heated to produce any change of colour, promise to give additional value to this process by a thermometer. The knife edges attached to the pendulum described by Capt. Kater, (*Phil. Trans.* 1818, p. 38.) were forged by Mr Stodart, from a piece of fine wootz. They were carefully hardened, and tempered in the bath at 430°; on trial they were found too soft. They were a second time hardened, and then heated to 212°. The intention was to increase the heat from that point, trying the temper at the advance of about every ten degrees. In the present instance this was not necessary, the heat of boiling water proving to be the exact point, at which the knife edges were admirably tempered.

highly probable that steel, for many uses, may be suffi- tempered in a range so extensive as from 212° to 430°, y the thermometer, all the intervening degrees may cer- be ascertained.

t the colour produced on the surface of heated steel is the of oxidation, is proved from the circumstance that when heated and suffered to cool under mercury or oil, none colours appear: nor do they when it is heated in hydro- nitrogen.

Alloys. l admits of being alloyed with several other metals, and oys, as appears from a recent investigation of Messrs. t and Faraday* are applicable to various uses.

SECTION X. *Zinc.*

Method of obtaining pure zinc. 1. ZINC is found in the state of oxide and of sulphuret. be obtained pure by dissolving the zinc of commerce in sulphuric acid, and immersing a plate of zinc for some in the solution, which is then filtered, decomposed by ate of potassa, and the precipitate ignited with charcoal in a or earthen retort.

nmon zinc, known in commerce by the name of *speltre,* ılly contains a portion of lead, copper, iron, traces of c and manganese, and a little plumbago: these impurities n in the form of a black powder when it is dissolved in sulphuric acid.

: is a bluish white metal, specific gravity 7, malleable at but very brittle when its temperature approaches that of which is about 680°. It is somewhat ductile, but its ossesses little tenacity.

Oxide. 5. *Oxide of Zinc* is obtained by heating the metal ex- to air. At a red heat it takes fire, burns with a bright and is converted into a white flocculent substance, for- called *pompholix*, *nihil album*, *philosopher's wool*, and *s of zinc.* This oxide, however, when once deposited, onger volatile; but if exposed to a violent heat, runs into

Composition. It has been examined with much attention by Proust, found it to consist of 80 parts of zinc and 20 oxygen. ussac† and Berzelius‡ have since investigated it, and in considering it as composed of

Zinc	80,39	100
Oxygen	19,61	24,4
	100,	124,4

Equivalent number. equivalent number deducible for zinc from the composi- the oxide, is 41 on Dr Wollaston's scale =,33 when

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Trans. 1822, and Boston Jour. Philos. i. 180.

le Chim. 80, 170.

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oxygen is denoted by 8. Mr Brande, from the composition of the oxide prepared by nitric acid, has fixed on 35 to denote the weight of the atom of zinc.* It will, probably, not be far from the truth, if we take the equivalent of zinc to be 33, and that of its oxide 33 + 8 = 41.† H. 2. 12.

This oxide is white, tasteless, and soluble in the alkalies. As prepared by combustion it contains small particles of the metal, which always render it gritty; hence, for pharmaceutical use, it is best prepared by precipitating solution of sulphate of zinc by ammonia, and washing and drying the precipitate. It is sometimes used as a pigment, both with oil and water; and is employed in medicine as a tonic, and as an external application.

Decomposes water. 1146. Zinc decomposes water very slowly at common temperatures, requiring, probably, the access of air; but acts with great rapidity, if the vapour of water be brought into contact with it when ignited. In whatever way it is oxidized, we obtain the compound already described, which is the only known oxide of zinc. H.‡

Chloride. 1147. *Chloride of Zinc* is formed by heating leaf zinc in chlorine, or by evaporating muriate of zinc to dryness and heating the residue red-hot in a glass tube. The compound is fusible under a dull red heat, and, on cooling, goes through several degrees of consistency, being viscid before it becomes solid. It is very deliquescent, and produces a *muriate of zinc* by the action of water. It appears from the analysis of Dr Davy to consist of equal weights of chlorine and zinc. It was formerly called *butter of zinc.*

The attraction of zinc for chlorine is very great, and this metal may therefore often be employed for separating chlorine from other combinations.§

Muriate. 1148. *Muriate of Zinc.* Muriatic acid, a little diluted, acts on zinc, and evolves hydrogen gas of great purity. The solution is clear, but cannot be brought to crystallize by evaporation. The dry chloride, however, may be sublimed, and passes over in a half solid state, from which circumstance it was called butter of zinc When rapidly evaporated, the muriatic solution yields a thick extract, which has somewhat of the viscidity of bird-lime. H.

1149. Muriate of zinc in strong solution, deposits oxide on adding water, and on being filtered and further diluted, more oxide separates. Weak solutions, when concentrated by evaporation, dissolve the oxide, which will precipitate again, on dilution. The solution is always slightly acid, and ammonia, when added, does not render it neutral, until all the oxide of zinc is precipitated.* H. 2. 14.

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* Quarterly Journal, xiv. 49.

† 43 Brande.

‡ When Pulverized Zinc is added to fused nitre, or projected with that salt into a red-hot crucible, a very violent detonation takes place; the Zinc is oxidized and part of the oxide combines with the alkali forming a soluble compound. C.

§ *Chlorate of Zinc* crystallizes in octoëdra, and is a very soluble salt.

1150. *Iodine and Zinc* readily combine, and produce a fusible, volatile, and crystalline compound, which, when exposed to air, deliquesces into *hydriodate of zinc.*†

1151. *Nitrate of Zinc.* Nitric acid, moderately strong, acts on zinc with great violence. The solution, by evaporation, crystallizes in four sided prisms, and affords a deliquescent salt, copiously soluble in water and alcohol, and consisting of 41 oxide + 54 nitric acid = 95. H. Nitrate.

1152. Liquid ammonia readily dissolves oxide of zinc, and even acts upon the metal. The concentrated solution of the oxide furnishes feathery crystals; it is decomposed by the acids, and the immersion of a plate of copper causes a precipitation of a part of the zinc, the ammonia, acquiring at the same time a blue colour.—DE LASSONE, *Ann. de Chim.* xxxv. 53.

1153. *Sulphuret of Zinc* exists native under the name of *Blende.* It may be formed artificially by heating oxide of zinc with sulphur, and is then of a yellow brown colour. It consists of 33 zinc + 16 sulphur = 49.‡ Sulphuret.

Blende is a brittle soft mineral, of different shades of brown and black. Its primitive form is the rhombic dodecaëdron. It usually contains traces of iron and lead. It is an abundant mineral, and important as a source of the pure metal, which is obtained by roasting the ore, and afterwards exposing it to heat in proper distillatory vessels, mixed with charcoal. The English miners call it *black jack.* It has been analyzed by Dr Thomson and found to consist of zinc 67,19 + sulphur 32,81 = 100. Native.

1154. *Hyposulphite of Zinc* was formed long ago by Fourcroy, who considered it as a *sulphuretted sulphite.* He formed it by digesting metallic zinc in sulphurous acid, sulphuretted hydrogen is disengaged. and by gentle evaporation crystals are obtained, which are to be digested in alcohol; this liquid dissolves the hyposulphite, and affords it in prismatic crystals. A mixture of oxide of zinc and sulphur treated by sulphurous acid affords the same salt; it is efflorescent, and easily decomposed by heat.—FOURCROY, *Système des connoissances Chymiques,* v. 380 § Hyposulphite

1155. *Sulphate of Zinc.* Zinc readily dissolves in diluted sulphuric acid, with the exception of a small quantity of black powder, which Vogel found to be composed of charcoal, iron, and sulphate of lead. The acid during its action on this metal Sulphate.

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* Quart. Jour. vi. 159.

† When this salt is mingled with perchloride of mercury, a precipitate is obtained of a beautiful bright red colour. When iodate of potassa is added to solution of sulphate of zinc, it forms an insoluble iodate of zinc.

‡ Mr E. Davy, by passing the vapour of sulphur over melted zinc, obtained a white crystalline substance, resembling the natural compound of zinc and sulphur, which is called *phosphorescent blende.*

§ *Sulphite of zinc* is easily formed by dissolving the oxide in sulphurous acid; it is more easily crystallizable than the hyposulphite and is insoluble in alcohol.

evolves hydrogen gas; (328) and the gas, when obtained, besides other impurities, holds in combination a portion of the metal (330).[*] H. 2. 13.

1156. When the solution of zinc in sulphuric acid is evaporated, it shoots into crystals which are right rhombic prisms.[†] This salt is soluble in 2,5 parts of water at 60°, and its solution is not precipitated by any other metal. Its composition is stated by Berzelius and Wollaston as follows.

Composition.

			Atoms.
Acid	30,86	27,3	1 = 40
Base	32,69	28,4	1 = 41
Water	36,45	44,3	7 = 63
	100,[‡]	100,[§]	144. H. 2. 14.

Sulphate of zinc is prepared for the purposes of the arts from the native sulphuret, and is usually in the form of a white amorphous mass, called *white vitriol.*

Native Sulphate of Zinc is found in places where the sulphuret of zinc occurs; it is probably the result of the decomposition of that ore.

Phosphuret.

1157. *Phosphuret of Zinc* is of a whitish colour, and a metallic lustre not unlike lead. It has some malleability, exhales a phosphoric smell, and at a high temperature, burns like common zinc. H.

Phosphate.

1158. *Phosphate of Zinc* is not crystallizable. It may be obtained by dissolving zinc in phosphoric acid, and evaporation to dryness. A phosphate of zinc is also precipitated upon the addition of phosphate of soda to sulphate of zinc. These salts have not been precisely examined, but it is probable there is a phosphate and a bi-phosphate of zinc.

Carbonate.

1159. *Carbonate of Zinc* occurs native, forming one of the varieties of the mineral called *calamine.* It may be formed by adding carbonate of potassa to sulphate of zinc. It is white and tasteless.

The primitive form of calamine, which occurs both crystallized and massive, is an obtuse rhomboid. It is often found investing carbonate of lime, which has sometimes been decomposed, and the calamine remains in pseudo-crystals. A variety of calamine, containing siliceous earth, is known by the name of *electric calamine,* from its property of becoming electrical when gently heated.

Process for obtaining zinc from its ores.

1160. The zinc of commerce is procured from the native sulphuret and from calamine by the following process. The

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[*] Hydrogen gas, holding zinc in solution, may be obtained by a process of Vauquelin. A mixture of the ore of zinc, (blende, or calamine) with charcoal, is to be put into a porcelain tube, which is to be placed horizontally in a furnace, and, when red-hot, the vapour of water is to be driven over it. The gas produced is a mixture of carbonic acid, carburetted hydrogen, and a solution of zinc in hydrogen gas, which has been called *hydrozincic gas.* The zinc is deposited on the surface of the water, over which this gas is kept; but if burned when recently prepared, the gas exhibits, in consequence of this impregnation, a distinctly blue flame.

[†] Brooke, in Ann. Philos.

[‡] Berzelius.

[§] Wollaston.

is first picked and broken into small pieces, and then sub-
ted to a dull red heat in a reverberatory furnace, by which
onic acid is driven off from the calamine, and sulphur from
blende. It is then washed, ground, and thoroughly mixed
about one eighth its weight of powdered charcoal. This
ture is put into large earthen pots, not unlike oil jars, six of
ch are usually placed in a circular furnace; each pot has an
tube passing from its lower part, through the floor of the
ace, and dipping into water, they are every where else
ly luted: upon the application of a red heat, the metal dis-
through the tube into the water beneath, whence it is col-
ed, melted, and cast into cakes.

General properties of salts of zinc.

161. Ferrocyanate of potassa produces a yellowish white
cipitate in solutions of zinc. The salts of zinc are mostly
ble in water, and the solutions are colourless and transparent:
y are not precipitated by hydriodic acid. Potassa, soda, and
nonia, form white precipitates, soluble in excess of the alkali,
sulphuric acid. Hydrosulphuret of ammonia, produces a
lowish white precipitate. The soluble phosphates, carbo-
es, and borates, produce white precipitates.

Alloys.

162. *Alloys of Zinc.*—With potassium and sodium zinc
ns brittle alloys, decomposable by exposure to air and water.
alloy with manganese is unknown. With iron it forms a
ite, and somewhat malleable alloy, which is difficult to form;
if plates of hot iron be dipped into melted zinc, they
uire the appearance of tin-plate.

t has been proposed to apply zinc to the purpose of
inary vessels, pipes for conveying water, sheathing for ships,
; but it is rendered unfit for the first object, by the facility
h which the weakest acids act upon it, and for the remain-
ones, by its considerable though slow oxidation, when ex-
ed to the operation of air and moisture. H. 2. 16.

SECTION XI. *Tin.*

163. THE properties of tin must be examined in the state of
in-tin or block tin; what is commonly known by the name
in, being nothing more than iron plates with a thin covering
this metal. Several varieties of tin are met with in com-
ree, for the discrimination of which, and the means of judg-
of their purity, Vauquelin has given useful instructions in
77th volume of the Annales de Chimie, and an interesting
ount of the ores of tin, and of the processes for extracting
metal in Cornwall, has been given by Mr Taylor in the 5th
ume of the Transactions of the Geological Society of Lon-
. H. 2. 35.

164. This metal has been known from the remotest ages. It
in common use in the time of Moses, and was obtained at a

very early period from Spain and Britain by the Phœnicians.—Pliny, lib. iv. cap. 34, and xxxiv cap. 47.

To obtain pure tin.

The native oxide is the principal ore of tin; the metal is obtained by heating it to redness with charcoal. To obtain pure tin the metal should be boiled in nitric acid, and the oxide which falls down reduced by heat in contact with charcoal in a covered crucible. U. The process is described at length in Aikin's *Dictionary*, (*Art.* Tin.)

Properties.

Tin has a silvery white colour, is considerably harder than lead, scarcely at all sonorous, very malleable, though not very tenacious. Under the hammer it is extended into leaves, called *tin-foil*, which are about $\frac{1}{1000}$th of an inch thick.* Its specific gravity is 7,30. It melts at 442°, and by exposure to heat and air is gradually converted into a grey peroxide. Placed upon ignited charcoal under a current of oxygen gas, it burns very brilliantly.

Powdered tin.

1165. A preparation under the name of *powdered tin* is sometimes directed to be prepared for pharmaceutical use, by shaking the melted metal in a wooden box rubbed with chalk on the inside: *tin filings* have also a place in some *Pharmacopœiæ*, and have been used as a vermifuge. These preparations are, however, both dangerous, the metal being rendered poisonous in the former case by slight oxidation, (Orfila, *Traité des Poisons*, T. i. 2me partie, p. 18.) and often creating very dangerous irritation when given in filings.

Protoxide.

1166. *Protoxide of Tin* is obtained by precipitating protomuriate of tin by ammonia; it falls in the state of hydrate; when dried, it is of a grey colour, and undecomposable by heat. It dissolves in the alkalies; exposed to heat and air it passes into the state of peroxide, undergoing a faint combustion. Its ammoniacal solution, when long kept, deposits metallic tin in arborescent crystals, and becomes a solution of the peroxide.

Peroxide.

1167. *Peroxide of Tin* is formed by treating the metal with nitric acid: there is a violent action attended by the formation of nitrate of ammonia. (472) Scarcely any of the metal is dissolved, but remains as a yellowish powder, which may be purified by washing. It is also formed by heating tin filings with red oxide of mercury; and by projecting a sufficient quantity of nitre upon red-hot tin. This oxide dissolves in the alkalies. Fused with glass it forms *White Enamel.* Heated intensely, it becomes insoluble in acids, and undergoes fusion.

Tin putty.

The substance called *Tin Putty*, is an oxide of tin formed by levigating the crusts of oxide that form upon the metal when kept for some time in fusion.

Native oxide.

1168. *Native Oxide of Tin* is found in Cornwall; in Spain; and in Saxony: it has also been found in Brittany, in France; in the East Indies; and in South America. The specific gravity of the native oxide is 7: its primitive crystal is an octoëdron with a square base.* In some of the valleys of Cornwall, tin is found in rounded nodules, of various sizes, mixed with pebbles and rounded fragments of rocks. To separate the tin from the alluvial matter, currents of water are passed over it, and hence these deposits have been called *stream works*, and the tin ore, *stream tin*. A modification of stream tin is called *wood tin*. It usually appears in small banded fragments of globular masses.

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* The process of making tin-foil consists simply in hammering out a number of plates of the metal, laid together upon a smooth block or plate of iron. The smallest sheets are the thinnest. U.

Wood tin.

1169. The number representing tin is 59. The protoxide consists of 59 tin + 8 oxygen. The hydrate of 67 protoxide + 9 water; and the peroxide of 59 tin + 16 oxygen. These numbers are deduced from the accurate analysis of Dr John Davy (*Phil. Trans.* 1812) and M. Gay-Lussac, (*Annales de Chimie*, lxxx.) The protoxide of tin, according to both these chemists, consisting of 100 tin + 13,5 oxygen; and the chloride, according to John Davy, of 100 tin + 60,71 chlorine.

Chloride.

1170. *Chloride of Tin* is procured by heating together an amalgam of tin and calomel; or more simply by heating protomuriate of tin in a retort till it fuses; it is a grey semi-transparent crystalline solid, which dissolves in water, forming a protomuriate of tin; it is volatile at a red heat, and consists of 59 tin + 36 chlorine. Heated in chlorine it burns into perchloride of tin.

Perchloride.

1171. If tin be heated in chlorine, or if amalgam of tin be distilled with corrosive sublimate, a *perchloride* is obtained; the best proportions are six parts of tin, previously combined with one of mercury, and intimately mixed with thirty of corrosive sublimate. The mixture is put into a glass retort with a sufficiently capacious receiver luted to it, and may be distilled over a small charcoal fire. The heat should be slowly raised to prevent too sudden action. Towards the end of the process a little chloride rises, which the old chemists, from its consistency and appearance, called *Butter of Tin*. It is a transparent colourless fluid, and when poured into water, is instantly converted into permuriate of tin. It consists of 59 tin + 72 chlorine. It was formerly called *Libavius's Fuming Liquor*: it exhales copious fumes when exposed to a moist air, and produces muriatic acid and oxide of tin. It is instantly decomposed by metallic zinc, forming chloride of zinc and a precipitate of metallic tin.

Proto-muriate.

1172. The *Protomuriate of Tin*, may be obtained by boiling one part of tin with two of muriatic acid, in a tubulated retort. The solution has always an excess of acid, is perfectly limpid and colourless; and contains the metal at the minimum of oxidation. It has a tendency, however to acquire a farther proportion of oxygen, and should, therefore, be carefully preserved from contact with the air. This property of absorbing oxygen is so remarkable, that it may even be applied to eudiometrical purposes. Proto-muriate of tin has, also, the property of reducing to a minimum of oxidation, those compounds of iron, in which the metal is fully oxidized, for example, it reduces the red sulphate to the green. It is a test also of gold and platinum, and blackens the solution of corrosive sublimate. With hydro-sulphurets it gives a black precipitate. H.

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* Brooke's Crystallography, 137. See also W. Phillips in Geological Trans. ii.

With solution of gold it produces a purple precipitate used in painting porcelain, and known under the name of *Purple of Cassius*. It crystallizes from its concentrated solution in small deliquescent needles. With infusion of cochineal it produces a purple precipitate. This muriate of tin is the *Sal Jovis* of old writers, Jupiter being the name by which the alchemists distinguished this metal.

A test of mercury.

1173. Recent muriate of tin is a very delicate test of mercury. M. Chenevix says, if a single drop of a saturated solution of neutralized nitrate, or muriate of mercury, be put into 500 grs of water, a few drops of solution of muriate of tin will render it a little turbid, and of a smoke-grey; and the effect is perceptible with ten times as much water. U. 749.

1174. The protomuriate of tin appears to be composed of 67 protoxide + 37 muriatic acid, or of

Composition.

Muriatic acid	35,5	100	55
Protoxide of tin	64,5	182	100
	190,		H. 2. 40.*

Submuriate.

1175. When potassa is added to muriate of tin, a *submuriate* of the protoxide is thrown down, consisting, according to Dr Davy of 134 protoxide + 37 acid, or of

Muriatic acid	19,0	100
Protoxide	70,4	364
Water	10,6	
	100.	

Nitro-muriate.

1176. *Nitro-muriate of Tin.* The nitro-muriatic acid (formed by mixing two or three parts of muriatic acid and one of nitric,) dissolves tin abundantly, with violent effervescence, and with so much heat, that it is necessary to add the metal slowly by successive portions. The solution is apt to congeal into a tremulous gelatinous mass; and if water be added, it is partly decomposed, and some oxide separated. The solution, used by the dyers, is prepared with that dilute nitric acid called single aqua-fortis, to each pound of which are added from one to two ounces of the muriate of soda or ammonia. This compound acid is capable of taking up about an eighth its weight of tin. H. 2. 41.

The solution is employed to heighten the colours of cochineal, gum-lac and some other red tinctures, from crimson to a bright scarlet in the dyeing of woollens.

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* On the preparation of muriate of tin, see Berard, Ann. de Chim. lxviii. 78; or Nicholson's Jour. xxvi, and Chaudet, Ann. de Chim. et Phys. iii. 370.

1177. The permuriate of tin forms acicular crystals in the upper parts of the phials containing the bi-chloride imperfectly secured from air. The addition of the pure alkalies to this salt of tin, occasions a precipitate which has not been accurately examined, but is said to be a *subpermuriate.* The peroxide of tin is more readily soluble in alkalies than the protoxide; it has been hence termed *Stannic acid.**

Nitrate. 1178. *Nitrate of Tin.* When nitric acid, highly concentrated, is poured upon tin filings, very little effect is produced; but when a small quantity of water is added, a violent effervescence follows; and the metal is reduced to a bulky powder, which is the white oxide retaining a little acid. If more water be added, an acid liquor is obtained, holding very little tin in solution; and containing nitrate of ammonia, the alkaline base of which is formed by the simultaneous decomposition of the water and nitric acid, and the union of the hydrogen of the former with the nitrogen of the latter. (472) H. Tin, however, is slowly dissolved, without effervescence, in nitric acid greatly diluted; the solution is yellow and will not crystallize; exposed to air it absorbs oxygen and peroxide of tin precipitates.

Sulphuret. 1179. *Tin and Sulphur.* Tin unites with sulphur, but requires, for its combination, so high a temperature, that at the moment of union there is too small a quantity of sulphur present, to saturate the tin, and a mechanical mixture results, of tin and sulphuret of tin. The only method of obtaining the saturated sulphuret is to melt the *aurum musivum,* which will presently be described, in close vessels. The *protosulphuret* is of a bluish colour and lamellated structure.

It is composed, according to Dr John Davy and Berzelius, of proportional metal + 1 sulphur, or

Composition.

Tin	78,6	100,
Sulphur	21,4	27,234
	100,	127,234

Aurum musivum. The second sulphuret, or *bisulphuret* of tin (*aurum musivum,*) is formed by heating sulphur with peroxide of tin, or, by heating in a matrass a powdered amalgam of 12 parts of tin and 6 of mercury, mixed with 7 parts of flowers of sulphur and of muriate of ammonia. A gentle heat is to be applied till the white fumes cease to appear, when the heat is to be raised to redness, and kept so for some time. On cooling, the *aurum musivum* (or *Mosaic Gold*) may be obtained by breaking the matrass. It is of a beautiful gold colour, and flaky in its structure. H. 2. 41.†

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* *Iodide of Tin* may be formed directly by heating the metal with iodine; or indirectly by adding hydriodic acid to a solution of muriate of tin. It is an orange-coloured compound, and has not been analysed.

† See Phil. Trans. 1771.—This process is thus explained. As the heat increases, the tin, by stronger affinity, seizes and combines with the muriatic acid of the muriate of ammonia, while the alkali of that salt, combining with a portion of the sulphur, flies off in the form of a sulphuret. The combination of tin

Properties.

1180. Aurum musivum has no taste, is not soluble in water, acids or alkaline solutions. But in the dry way it forms a yellow sulphuret, soluble in water. It is used as a pigment for giving a golden colour to small statue or plaster figures. It is likewise said to be mixed with melted glass to imitate lapis lazuli. U. 208.

The sulphurets of tin consist respectively of 59 tin + 16 sulphur, and 59 tin + 32 sulphur.[*]

Sulphate.

1181. *Sulphate of Tin.* When tin is boiled in sulphuric acid, a solution is obtained which deposits white acicular crystals. A protosulphate of tin is also precipitated by pouring sulphuric acid into protomuriate of tin. If the sulphate be long boiled, a copious white precipitate subsides, which will not again dissolve. It is composed of the white oxide retaining only a small portion of acid, and constituting in fact a subsulphate. H.[†]

Characteristics of the salts of tin.

1182. The salts of tin are mostly soluble in water. They are precipitated of an orange colour by hydriodic acid, and by hydrosulphuret of ammonia, provided no excess of acid be present. Solution of muriate of gold, and of corrosive sublimate produce purple and black precipitates in the salts of tin containing the protoxide, but none in those containing the peroxide. Ferrocyanate of potassa produces a white precipitate in solution of muriate of tin. A plate of lead frequently throws down metallic tin, or its oxide, from the saline solutions.

Alloys.

1183. Tin forms useful alloys with many of the metals. *Pewter* is one of these; and the best kind of it is entirely free from lead, being composed chiefly of tin with small proportions of antimony, copper and bismuth.[‡] An amalgam formed by gradually adding three parts of mercury to twelve of tin melted in an iron ladle, and stirring the mixture, is much used in silvering looking glasses. H. With potassium and sodium, tin forms brittle white alloys. Its alloy with manganese is not known. It does not readily combine with iron, but tin-plate

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and muriatic acid sublimes, and is found adhering to the sides of the matrass. The mercury, which served to divide the tin, combines with part of the sulphur and forms cinnabar, which also sublimes; and the remaining sulphur, with the remaining tin, forms the aurum musivum, which occupies the lower part of the vessel. It must be admitted, however, that this explanation does not indicate the reasons why such an indirect and complicated process should be required to form a simple combination of tin and sulphur. U.

[*] *Hyposulphite of Tin*, has not been examined. Muriate of tin forms no precipitate with the alkaline hyposulphites. *Sulphite of Tin* is formed by digesting the protoxide in sulphurous acid, but the salt has not been examined.

[†] *Hydrosulphuretted Oxide of Tin* is yellow brown, and formed by pouring solution of sulphuretted hydrogen into dilute muriate of tin. *Phosphuret of Tin* may be formed by dropping phosphorus into melted tin. It is of a silvery colour, sectile, and somewhat ductile. When its filings are sprinkled upon hot coals the phosphorus burns. *Phosphite of Tin* has not been examined. *Phosphate of Tin* is formed by adding phosphate of soda to the solutions of tin. It is a white powder, not soluble in water and fuses at a red heat into an opaque white enamel. *Carbonate of Tin*—When carbonate of potassa is added to protomuriate of tin, a white precipitate ensues, which, when washed and dried effervesces copiously with the acids. *Borate of Tin* is an insoluble white powder.

[‡] On the alloys of tin, a memoir of M. Dussausoy may be consulted in the 5th vol. of Ann. de Chim. et Phys.; and Mr Chaudet's paper in the same, and in the 7th volume.

may be considered as an imperfect alloy of those metals. With zinc it forms a hard brittle alloy.

SECTION XII. *Cadmium.*

Discovery.

1184. CADMIUM was discovered in the autumn of 1817, by Stromeyer, in an oxide of zinc, which had been prepared for medicinal use from an ore of zinc brought from Silesia. He ascertained its principal properties and combinations; and has since extracted it from various other ores of zinc.* Dr Clarke has shown that it exists in the ores of zinc from Derbyshire and Mendip, and in the zinc of commerce;† and Mr Herapath, of Bristol, has pointed out an abundant source of it in the sublimate, which, in the process for obtaining zinc by distillation, rises before the zinc, in what the workmen call the *brown blaze*. Of this sublimate, which is attached to the roof of the vault, it forms from 12 to 20 per cent.‡

Method of detecting cadmium.

1185. The presence of cadmium, in an ore of zinc suspected to contain it, may be discriminated by directing the blue flame of a candle upon a small fragment placed on a slip of platinum foil. If any cadmium be present, its oxide will be reduced, volatilized, and carried along the slip of platinum, coating it with its peculiar reddish-brown oxide. Dr Wollaston, to detect cadmium, dissolves the ore of zinc in muriatic acid, gets rid by heat of the excess of acid, and adds distilled water. All the metals that iron will precipitate he removes by a rod of iron, and filters the liquor into a platinum capsule containing a piece of zinc. The cadmium, if any be present, will coat over the surface of the capsule with a precipitate of a dull leaden hue, and will adhere so firmly that it may be washed, and thus freed from any remaining solution of zinc. Muriatic acid will dissolve the lead-coloured precipitate with effervescence, and either carbonated or caustic potassa will yield a white precipitate; which may be tested before the blow-pipe in the manner already described.

Of separating from zinc ores.

1186. To separate cadmium from the ores of zinc, Stromeyer dissolves the ore in sulphuric acid; and through the solution, which ought to contain an excess of acid, sends a current of sulphuretted hydrogen gas. The precipitate is well washed, dissolved in concentrated muriatic acid, and the excess of acid expelled by evaporation. The residue is dissolved in water, and precipitated by carbonate of ammonia, an excess of which must be added to re-dissolve any zinc or copper that may have been thrown down by the sulphuretted hydrogen gas. Carbonate of cadmium alone remains, which, after being heated to drive off the carbonic acid, is reduced by mixing it with lampblack, and exposing it to a moderate red heat in a glass or earthen retort.

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* Ann. Philos. xiv. 269.

† Ann. Philos. xv. 272, and N. S. iii. 123.

‡ Ibid 435.

Properties. 1187. Cadmium resembles tin very nearly in colour, lustre, and in the sound it emits when bent. It is somewhat harder than tin, and surpasses it in tenacity. It is very ductile, and may be reduced to fine wire, or thin plate; yet when long beaten, it scales off in different places. Its specific gravity is 8,604 before hammering, and 8,694 afterwards; or, according to Mr Children,* 8,67 before, and 905 after being hammered. It melts at a heat below redness, and is volatilized by a heat not much greater than that required to vaporise mercury. Its vapour has no odour. It condenses in drops as readily as mercury, and these, on congealing, present distinct traces of crystallization.

Oxide. 1188. Cadmium is as little altered by exposure to the air as tin. When heated in the open air, it burns as readily as the latter metal, and is converted into a brownish-yellow oxide. This oxide, which is its only one, consists of 100 metal + 14,352 oxygen;† which gives 56 for the equivalent number of the metal, and 64 for that of the oxide. This oxide is soluble in ammonia, but not in carbonate of ammonia, or in potassa, or its carbonate, which even precipitate it from its solution in ammonia. By availing himself of this property, Mr Children separated it from oxide of zinc, which is not thrown down by the fixed alkali, and thus verified its presence in compounds containing much zinc and little cadmium.

1189. With the acids, oxide of cadmium unites and forms salts, which agree in the following characters. Fixed alkalies throw down a white hydrated oxide, as does ammonia, with this difference, that the latter, added in excess, re-dissolves the precipitate. Prussiate of potassa causes a white sediment, as does oxalate of ammonia. Sulphuretted hydrogen, and the hydro-sulphurets, throw down cadmium of a yellow or orange colour, like orpiment. No change is produced by chromate of potassa, succinate or benzoate of ammonia, infusion of galls, or sulphate of soda.

Chloride. 1190. *Chloride of Cadmium* crystallizes in small rectangular prisms, perfectly transparent, which effloresce when heated, and are very soluble. At a high temperature, it sublimes in small micaceous plates: 100 parts of the fused chloride consist of 38,61 chlorine + 61,39 metal. This gives 57 for the equivalent of cadmium, differing very little from the number deduced from the oxide.

Iodide. 1191. *Iodide of Cadmium* forms large and beautiful hexaëdral tables, of a metallic or pearly lustre. At high temperatures, the iodine escapes. It consists of 100 metal + 227,43 iodine.

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* Quart. Jour. vi. 226.

† Stromeyer.

1192. *Nitrate of Cadmium* crystallizes in prisms or needles, which are deliquescent. Its constituents are 100 acid + 117,58 oxide. Nitrate.

1193. The *sulphate* crystallizes in large rectangular prisms resembling sulphate of zinc, which are very soluble in water. They effloresce in the air, and at a gentle heat lose their water of crystallization, amounting to 34,26 on 100 of the dry salt. The neutral sulphate consists of 100 acid + 161,12 oxide. Sulphate.

1194. The *Carbonate* is pulverulent and insoluble in water, and readily decomposable by heat. It consists of 100 acid + 292,88 oxide. Carbonate.

1195. The *phosphate* is pulverulent and insoluble. It is constituted of 100 acid + 225,49 oxide.

1196. Cadmium unites with sulphur, as with oxygen, in only one proportion, which is that of 100 metal to 28,172 sulphur. The sulphuret has a yellow colour with a shade of orange. Concentrated muriatic acid acts readily upon it, and evolves sulphuretted hydrogen gas. The sulphuret may be formed by heating sulphur either with the metal or the oxide, or by precipitating a solution of cadmium by sulphuretted hydrogen. Union with sulphur.

1197. *Phosphuret* of cadmium has a grey colour and a feeble metallic lustre.

1198. Cadmium unites with other metals. Its alloy with copper is white, with a slight tinge of yellow. It unites also with cobalt, platinum, and mercury, and probably with other metals. Alloys.

From a survey of its salts, it appears that their analysis does not lead to a perfect agreement as to the equivalent of its oxide, and consequently of that of the metal. None of the results, however, are very remote from affording 64 for the number representing the oxide, from which deducting 8, we obtain 56 for the equivalent of cadmium. H. 2. 43. Equivalent number.

SECTION XIII. *Copper.*

1199. THIS metal is found native, and in various states of combination. Of its ores, the oxide, chloride, sulphuret, sulphate, phosphate, carbonate, and arseniate, are the most remarkable. The metal may be obtained perfectly pure by dissolving the copper of commerce in muriatic acid; the solution is diluted and a plate of iron immersed, upon which the copper is precipitated. It may be fused into a button, after having been previously washed in dilute sulphuric acid to separate a little iron that adheres to it. Pure copper, how obtained.

It was known in the early ages of the world, and was the principal ingredient in domestic utensils, and in the instruments of war, previous to the discovery of malleable iron. The word *copper* is derived from the island of Cyprus, where it was first wrought by the Greeks.

Properties.

1200. Copper has a fine red colour, and much brilliancy; it is very malleable and ductile, and has a peculiar smell when warmed or rubbed. It melts at a cherry red or dull white heat. Its specific gravity is 8,90. Under a flame, urged by oxygen gas, it takes fire, and burns with a beautiful green light.

Oxidation of

1201. Copper is oxidized by air. This may be shown by heating one end of a polished bar of copper, which will exhibit various shades of colour, according to the intensity of the heat.

A plate of copper, exposed for some time to heat, becomes covered with an oxide, which breaks off in scales when the copper is hammered. It is composed of 62 of the black oxide and 38 copper. This oxide, when exposed on a muffle, is farther oxidized, and assumes a deep red hue. Copper is also oxidized by long exposure to a humid atmosphere, and assumes a green colour; but the green compound holds carbonic acid in combination. The oxides of copper do not return to a metallic state by the mere application of heat; but require, for their reduction the admixture of inflammable matter.

Native.

1202. *Native Copper* occurs in a variety of forms; massive, dendritic, granular, and crystallized in cubes, octoëdra, &c. It is found in Cornwall, Siberia, and other parts of Europe. Large masses have been found in various parts of America; one of which, about 30 miles from Lake Superior, described by Mr Schoolcraft, weighs by estimation 2,000 lbs.*

Protoxide.

1203. *Copper and Oxygen.* Copper is susceptible of only two degrees of oxidizement; in its lower stage the compound is red; when oxidated to the maximum, it is black. The red or *Protoxide* occurs native. It may be formed artificially, by digesting a mixture of metallic copper, and peroxide of copper, in muriatic acid. Mr Chenevix recommends the following process. Mix together 57½ parts of black oxide of copper, precipitated from the sulphate on an iron plate. Triturate it in a mortar, and put the mixture with 400 parts of muriatic acid, into a phial, which is to be well stopped. The copper and its oxide will be dissolved with heat. When potash is poured into this solution, the oxide (or rather hydrated protoxide) of copper is precipitated of an orange colour. This oxide, when deprived of water, becomes red; but it attracts oxygen so strongly that it can scarcely be dried without absorbing more. It is composed of

How obtained.

Composition.

Copper	88,89	100.
Oxygen	11,11	12,5
	100.	H. 2. 90.

Equivalent number.

1204. The equivalent number of copper, deducible from the composition of the protoxide, is therefore 64, for 12,5 : 100 : : 8 : 64, and the protoxide will consist of 1 atom copper = 64 + 1 atom of oxygen 8 = 72.

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* See other localities in Cleaveland's Mineralogy, p. 554.

The *Ruby Copper* of mineralogists is a native Protoxide.

Peroxide.

1205. *Peroxide* of Copper may be obtained, either by calcining the scales of copper, which have already been alluded to, under a muffle; or by decomposing nitrate of copper by carbonate of potassa. and igniting the precipitate; or by the simple ignition of the nitrate. It is composed of

Composition.

Copper	80	100
Oxygen	20	25
	100.	H. 2. 89.

1206. The composition of this oxide is learned by dissolving 100 grains of pure copper in nitric acid, evaporating to dryness, and giving the residue a red heat in a porcelain crucible; it is peroxide of copper, and weighs 125 grains: considering this as a compound of 1 proportional of copper and 2 of oxygen, the number 64 will represent the metal; for, 25 : 100 : : 16 : 64.

100 grains of pure native protoxide of copper in octoëdral crystals, dissolved in muriatic acid, furnished a precipitate of 89 grains of metallic copper upon a plate of iron, so that the protoxide consists of 89 copper + 11 oxygen; and 11 : 89 : : 8 : 64.7. B.

This number closely accords with that derived from the analysis of the chloride.

Chlorides.

1207. *Copper and Chlorine.* Gaseous chlorine acts upon copper with great energy, and produces two chlorides; the one a fixed fusible substance, which is the protochloride, consisting of 1 proportional of copper = 64 + 1 proportional of chlorine = 36. The other a volatile yellow substance, which is a perchloride, and contains 64 copper + 72 chlorine.

Proto-chloride, how obtained

1208. The *Protochloride of Copper* was first described by Boyle in 1666, under the name of *Rosin of Copper.* It may be obtained by exposing copper filings to the action of chlorine not in excess; or by evaporating the protomuriate, and heating the residue in a vessel with a very small orifice; or by heating the perchloride in the same way. It is also the residue of the distillation of a mixture of two parts of corrosive sublimate and one of copper filings. It is insoluble in water, but soluble in muriatic acid, from which potassa throws down a protoxide. When water is added to its muriatic solution it is precipitated unaltered; its colour varies, being generally dark brown; but if fused and slowly cooled, it is yellow, translucent, and crystalline.

Converted into sub-permuriate.

1209. When moistened chloride of copper is exposed to air, it acquires a greenish white colour, and becomes converted into a *subpermuriate of copper.* The same compound may be formed by adding hydrated peroxide of copper to a solution of the permuriate; or by exposing to the atmosphere slips of copper partially immersed in muriatic acid. This compound consists of

2	proportionals peroxide of copper 80 × 2 =	160
1	———— muriatic acid	37
2	———— water	18
		215

Perchloride.

1210. *Perchloride of Copper* may be formed by dissolving peroxide of copper in muriatic acid, and evaporating to dryness by a heat below 400°. It is soluble in water, producing a permuriate, from which potassa precipitates the peroxide: its colour is yellow, but it becomes white and afterwards green when exposed to heat and moisture. Exposed to a red heat in a tube with a very small orifice, gaseous chlorine is expelled and it becomes a protochloride. (1209.)

Action of muriatic acid.

1211. Muriatic acid acts with difficulty on metallic copper, except it be concentrated and boiling; but it readily dissolves the peroxide, forming a brown or grass-green solution, according to its state of dilution. This is a *permuriate of copper*. If plates of copper be exposed to the joint action of air and the fumes of muriatic acid, they become incrusted with a green powder, which is readily soluble in muriatic acid, and which is the *subpermuriate*. (1290.)

Protomuriate.

If metallic copper be digested in muriatic acid with the peroxide, an olive-coloured solution of *protomuriate of copper* is formed which strongly attracts oxygen, and which, when concentrated, deposits small grey crystals. The addition of potassa occasions a precipitate of the orange or protoxide of copper,*(1203)* which according to Berzelius, consists of 100 copper + 12,5 oxygen. (*Annales de Chim.* lxxviii. 107.) Proust's analysis of the peroxide gives 100 copper + 25 oxygen, and these numbers furnish 64 as the equivalent of copper. (1205.)

Native submuriate, or atacamite.

1212. *Native Submuriate of Copper* is found in Peru and Chili, sometimes in the form of green sand, and sometimes massive and crystallized. The green sand was found in the river Lipas, in the desert of Atacama, separating Peru from Chili, hence mineralogists have termed this variety, *Atacamite*. Muriate of copper has also been found upon some of the lavas of Vesuvius. The primitive form of this substance is an octoëdron. It is of a deep green colour, and contains, according to Dr Davy's analysis, 73 peroxide of copper + 16,2 muriatic acid + 10,8 water.*

Nitrate.

1213. *Nitrate of Copper*. Nitric acid, diluted with three parts of water, rapidly peroxidizes copper, evolving nitric oxide, and forming a bright blue solution, which affords deliquescent prismatic crystals on evaporation, of a fine blue colour and very caustic. It consists of 80 peroxide + 108 acid; but the crystals contain a considerable portion of water, which causes them to liquefy at a temperature below 212°. At a higher temperature they lose water and acid, and according to Proust become a *sub-pernitrate*, which is insoluble in water, and entirely decomposed at a red heat. There appears to be no protonitrate f copper, for protoxide of copper, digested in very dilute nitric cid is resolved into peroxide which dissolves, and into metallic opper. Potassa forms, in this solution, a bulky blue precipitate of *hydrated peroxide of copper*, which when boiled in potassa or soda, becomes black from the loss of its combined water.

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* *Chlorate of Copper* is a blue-green deliquescent salt, difficultly crystallizable, formed by dissolving peroxide of copper in chloric acid. A piece of paper dipped into its solution burns with a remarkable green flame.—Vauquelin. An *Iodide of Copper* is precipitated from solutions of the metal by hydriodic acid. It is brown and insoluble. When solution of potassa is added to solutions of copper, an insoluble *iodate of copper* is thrown down.

Hydrated peroxide.

Exp.

1214. When crystals of nitrate of copper are coarsely powdered, sprinkled with a little water, and quickly rolled up in a sheet of tin foil, there is great heat produced, nitrous gas is apidly evolved, and the metal often takes fire.

Ammonio-nitrate.

1215. If ammonia be added to solution of nitrate of copper, it occasions a precipitate of the hydrated peroxide; but if t be added in excess, the precipitate is re-dissolved, and a triple *ammonio-nitrate of copper* is produced.

Ammoniuret of copper.

1216. If peroxide of copper be digested in ammonia it is dissolved, forming a bright blue solution, which by careful evaporation affords fine blue crystals. A mixture of lime, sal ammoniac, and water, placed in a copper vessel, or mixed with oxide of copper, also affords a fine blue liquor in consequence of the action of the ammonia on the oxide of copper. This solution is the *Aqua Sapphirina* of old pharmacy. The compound has sometimes been called *Ammoniuret of Copper*, or *Cuprate of Ammonia.*

1217. The protoxide of copper also dissolves in ammonia, but the solution is colourless; if it be exposed to air it becomes blue. This may be well shown by filling a tall glass with liquid ammonia, and adding a few drops of solution of protomuriate of copper; the liquid presently acquires a blue colour upon the surface, but remains for some time colourless below.

Exp.

Exp.

Into a half ounce stoppered phial, filled with a solution of ammonia, drop a few pieces of metallic copper; if the bottle be left unstopped, a beautiful blue liquid will be obtained; if the stopper be replaced, this colour in a short time will disappear, and re-appear on again admitting the air. In this manner a blue and colourless liquid can be alternately produced as we withdraw or replace the stopper. In this experiment the peroxide when excluded from the air, is converted into a protoxide by the action of the metallic copper, which again becomes the peroxide by the action of the atmosphere.

Brunswick green.

1218. Plates of copper digested in a solution of muriate of ammonia, are soon incrusted with a green powder, which has been used in the arts under the name of *Brunswick green.*[*]

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[*] According to Dr Mac Culloch a solution of copper in ammonia may be obtained by boiling metallic copper in water of ammonia. The water is decomposed, the metal is oxidated and hydrogen escapes. Advantage may be taken of this in cleaning (or colouring, as it is termed by jewellers) gold trinkets, such as chains, &c. which are often made of a very inferior alloy. Artists make use of weak nitric acid, or of the materials from which the acid is produced, and which often destroys the finer kinds of workmanship by dissolving the copper of the alloy to some depth on the surface; the gold not being acted upon, the trinket appears as if newly gilded. Boiling in ammonia is a safe substitute for this process and the operation may be performed by any person without the assistance of the artist Brewster's *Jour*. i. 75. *Best. Jour*. ii. 208.

Sulphurets.

1219. *Copper and Sulphur.* There are two sulphurets of copper, both of which exist native; the one is black and may be formed artificially, by mixing together 8 parts of copper filings, and 2 of sulphur, and exposing the mixture to a gentle heat.* Whenever the sulphur is raised a little above its melting

Exp.

temperature, combustion suddenly pervades the whole mass with explosive violence, exceeding in brightness that produced by the fusion of iron and sulphur.—The experiment succeeds equally well *in vacuo* or in azote. U. 370.†

Copper leaf, Berzelius observes,‡ burns in gaseous sulphur, as brilliantly as iron wire in oxygen gas. A compound is formed, precisely analogous to the native black sulphuret of copper, or *copper glance.* It is a *proto-sulphuret* and consists of

Copper	80	100	or 1 atom	= 64
Sulphur	20	25	,, 1 ,,	= 16
	100	125		80 H. 2. 98.

Bi-sulphuret.

1220. Bi-sulphuret of copper forms the principal ingredient of *copper pyrites*, or the yellow sulphuret, which is the most important and generally occurring ore, affording the largest proportion of the copper of commerce.§

Hyposulphite.

1221. *Hyposulphite of Copper* was formed by Mr Herschel by mixing hyposulphite of potassa with sulphate of copper. It is colourless; of an intensely sweet taste; and provided air be excluded, it is not turned blue by ammonia, which seems to show that the metal is in the state of protoxide.—*Edin. Philos. Jour.* i. 24.

Sulphite.

1222. *Sulphite of Copper* may be obtained by passing a current of sulphurous acid gas (which has been first passed through a small quantity of water, in order to deprive it of sulphuric acid) into a vessel containing water and peroxide of copper. A green liquid is formed, which contains sulphite of copper, with a large excess of acid; and sulphite of copper in very small red crystals, remains at the bottom of the vessel. This salt has been investigated by Chevreuil,[*] and found to consist of protoxide of copper 63,84 sulphurous acid 36,16. H.

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* Or by mixing 3 parts of the metal with 1 of sulphur, in a glass tube.

† From this experiment, Dr Ure remarks, we are entitled to consider sulphur as a true supporter of combustion, if this name be retained in chemistry,—and sulphur is at once a supporter and a combustible in the fullest sense; a fact fatal to this technical distinction, since one body cannot be possessed of diametrically opposite qualities. U. 370.

‡ 79 Ann. de Chim. 250. See also Vauquelin on the artificial Sulphuret of Copper, lxxi. 265. Berzelius states that 100 metal combine with 25,6 sulphur.

§ The Cornish mines are very productive of this ore, and it is the principal product of the Parys mountain mine in Anglesea.

The following is an outline of the process by which these ores of copper are reduced, as carried on upon a very large scale near Swansea, where the chief part of the Cornish ores are brought to the state of metal. The ore, having been picked and broken, is heated in a reverberatory furnace, by which arsenic and sulphur are driven off. It is then transferred to a smaller reverberatory, where it is fused, and the slag which separates, being occasionally removed, is cast into oblong masses used as a substitute for bricks. The impure metal collected at the bottom of the furnace is granulated by letting it run into water; it is afterwards re-melted and granulated two or three times successively, in order further to separate impurities, which are chiefly sulphur, iron, and arsenic, and ultimately cast into oblong pieces called *pigs*, which are broken up, roasted, and lastly melted with a portion of charcoal in the refining furnace. It is now malleable: and is generally rolled into plates, which are annealed, and when hot, quenched in urine, which gives the metal a peculiar red tinge. B.

1223. When sulphite of potassa is added to nitrate of copper a precipitate falls, which assumes the form of red and yellow crystals. The former are sulphite of copper; the latter a tripple *sulphite of potassa and copper*.—Chevreuil.

Persulphate or Blue Vitriol.

1224. *Persulphate of Copper.—Roman Vitriol.—Blue Vitriol.*—This salt is formed by dissolving peroxide of copper in sulphuric acid. It crystallizes in rhomboidal prisms of a fine blue colour, doubly refractive, and soluble in about 4 parts of water at 60°. It may also be formed by boiling copper filings in sulphuric acid; a process which furnishes abundance of sulphurous acid, but which is not generally had recourse to, to produce sulphate of copper. It is made upon a large scale, by exposing roasted sulphuret of copper to air and moisture. When heated it loses water of crystallization, and at a higher temperature sulphuric acid is evolved, unmixed with sulphurous acid, as in the case of the decomposition of protosulphate of iron, (1115) and peroxide of copper remains. It is the *Vitriol* or *Salt of Venus* of the alchymists. It consists of 80 peroxide + 80 sulphuric acid, when crystallized it contains 10 proportionals of water, and consequently its composition will stand thus:—

Composition.

1 proportional of peroxide	80
2 proportionals of sulphuric acid	80
10 proportionals of water	90
	250 B.

Strictly speaking this salt is a bi-sulphate. H.

There appears to be no *protosulphate* of copper, for when protoxide of copper is digested in dilute sulphuric acid, metallic copper is separated, and a solution of the peroxide obtained.

Subsulphate.

1225. By cautiously adding ammonia to a solution of the foregoing salt, a *subsulphate of copper* is precipitated, consisting of 160 oxide + 40 acid. The alkalies precipitate hydrated peroxide from the solution of the persulphate, and excess of ammonia forms a *triple sulphate of ammonia and copper*. The same compound is formed by triturating carbonate of ammonia with crystals of sulphate of copper. It is the *cupri ammoniaretum* of the U. S. *Pharmacopœia*.[†]

Phosphate.

1226. Phosphoric acid unites with peroxide of copper in two proportions. If solutions of phosphate of soda and sulphate of copper be mingled together, a bluish green precipitate is formed, consisting of

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[*] Ann. de Chim. 88. 181.

[†] *Sulphate of Copper and Potassa* is a triple salt formed by digesting peroxide of copper in bi-sulphate of potassa. It crystallizes in rhomboids of a pale blue colour. *Phosphorus and Copper* form a grey brittle phosphuret. It is most easily made by dropping pieces of phosphorus on red-hot copper wire. It is more fusible than copper.

1 proportional	peroxide of copper	80	55,35
2 ————	phosphoric acid	56	38,40
1 ————	water	9	6,25
		145	100,

It is therefore a *bi-phosphate*. The *phosphate* has not yet been formed artificially, but has been found native, of an emerald green colour. H.*

Carbonate.

1227. *Carbonate of Copper*, artificially prepared, by adding carbonate of potassa to sulphate of copper and drying the precipitate, is a green compound, insoluble in water, consisting, according to Mr R. Phillips, of 80 peroxide + 22 carbonic acid + 9 water. It is, therefore, a *supercarbonate*. Copper, exposed to damp air, becomes incrusted with this compound. Exposed to heat, it loses water and carbonic acid, and leaves the peroxide. In order to heighten the green tint for which this compound is esteemed as a pigment, it should be repeatedly washed with boiling water.

Verditer.

1228. There is a fine blue cupreous preparation, called *Refiner's Verditer*, principally made by silver refiners. It consists, according to Mr R. Phillips, of 3 proportionals of oxide, 4 of carbonic acid, and 2 of water. (*Quarterly Journal of Science and the Arts*, Vol. iv. p. 277.) There is a very inferior pigment, also called Verditer, which is a mixture of subsulphate of copper and chalk.

According to Pelletier, a good verditer may be obtained as follows: add a sufficient quantity of lime to nitrate of copper to throw down the hydrated oxide; it gives a greenish precipitate that is to be washed and nearly dried upon a strainer; then incorporate it with from 8 to 10 per cent. of fresh lime, which will give it a blue colour, and dry it carefully.

1229. According to Mr Chenevix, the alkaline carbonates dissolve a portion of the peroxide of copper, and form triple salts.

Native.

1230. *Native Carbonate of Copper* is found of a green and blue colour. The former, or *Malachite*, is found in various forms, but never regularly crystallized. It is of various shades of green, and often cut into small slabs, or used as beads and broach stones. The pulverulent variety has been termed *crysocolla* and *mountain green*.

Borate.

1231. *Borate of Copper*. Solution of borax, poured into sulphate of copper, produces a bulky pale green precipitate of borate of copper.

Ferrocyanate.

1232. *Ferrocyanate of Copper* is a brown compound, obtained by adding ferrocyanate of potassa to a dilute solution of sulphate or nitrate of copper. Mr Hatchett has recommended this substance as a brown pigment.

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* See Cleaveland's Mineralogy, 574.

Alloys.

1233. Many of the *alloys* of copper are important. With gold it forms a fine yellow ductile compound, used for coin and ornamental work. British sterling or standard gold consists of 11 gold + 1 copper. The specific gravity of this alloy is 17,157. With silver it forms a white compound, used for plate and coin. Lead and copper require a high red heat for union; the alloy is grey and brittle.—See *Gold* and *Silver*.

Of the alloys of copper with the preceding metals the most important are brass and bell-metal. It forms white compounds with potassium and sodium; a reddish alloy with manganese; and a grey one with iron.

Brass.

1234. *Brass* is an alloy of copper and zinc. The metals are usually united by mixing granulated copper with calamine (1159) and charcoal: the mixture is exposed to heat sufficient to reduce the calamine and melt the alloy, which is then cast into plates. The relative proportions of the two metals vary in the different kinds of brass; there is usually from 12 to 18 per cent. of zinc. Brass is very malleable and ductile when cold; and its colour and little liability to rust recommend it in preference to copper for many purposes of the arts. According to M. Sage, a very beautiful brass may be made by mixing 50 grains of oxide of copper, 100 of calamine, 400 of black flux, and 30 of charcoal powder; melt these in a crucible till the blue flame is no longer seen round the cover; and, when cold, a button of brass is found at the bottom, of a golden colour, and weighing one-sixth more than the pure copper obtained from the above quantity of oxide.

Analysis of brass.

1235. The analysis of brass may be performed by solution in nitric acid; add considerable excess of solution of potassa and boil, which will dissolve the oxide of zinc and leave that of copper; wash the latter, and dry and heat it to redness: 125 parts indicate 100 of copper. The zinc in the filtered alkaline solution may be precipitated by carbonate of soda, having previously added a small excess of muriatic acid; wash this precipitate, dry it, and expose it to a red heat; it is then oxide of zinc, 123 parts of which indicate 100 of metal.

Tutenag, pinchbeck, &c.

1236. *Tutenag* is said to be an alloy of copper, zinc, and a little iron; and *Tombac*, *Dutch gold*, *Similor*, *Prince Rupert's metal*, and *Pinchbeck*, are alloys containing more copper than exists in the brass, and consequently made by fusing various proportions of copper with brass. According to Wiegleb, *Manheim gold* consists of 3 parts of copper and 1 of zinc. A little tin is sometimes added, which, though it may improve the colour, impairs the malleability of the alloy.

Speculum metal.

1237. *Speculum metal* is an alloy of copper and tin, with a little arsenic; about 6 copper, 2 tin, 1 arsenic. On this subject the reader is referred to Mr Edwards's experiments.—Nicholson's *Journal*, 4to. iii.

Bell-metal and bronze.

1238. *Bell-metal* and *bronze* are alloys of copper and tin; they are harder and more fusible, but less malleable than copper;

the former consists of 3 parts of copper and 1 of tin; the latter of from 8 to 12 of tin with 100 of copper. A little zinc is added to small shrill bells.

1239. From a recent investigation, Mr Dalton finds that into all the alloys of copper which are characterized by useful properties, the ingredients enter in atomic proportions; and it is probable that by attention to these proportions, the manufacture of the artificial alloys may be greatly improved. H. 2. 99.

1240. The analysis of alloys of tin and copper may be performed by digestion in nitric acid, which dissolves the copper, and converts the tin into insoluble peroxide, which, when washed and dried, consists of 100 tin + 27 oxygen. The cupreous solution may be decomposed by potassa, and the pure peroxide of copper indicates the quantity of that metal, as in the analysis of brass. (1235)

1241. Vessels of copper used for culinary purposes are usually coated with tin, to prevent the food being contaminated with copper. Their interior surface is first cleaned, then rubbed over with sal-ammoniac. The vessel is then heated, a little pitch or rosin spread over the surface, and a bit of tin rubbed over it, which instantly unites with and covers the copper.

Characteristics of the salts of copper.

1242. The cupreous salts are nearly all soluble in water, and of a blue or green colour. Ammonia produces a compound of a very deep blue, when added in excess to these solutions, hydrosulphuret of ammonia forms a black precipitate; and a plate of iron plunged into a liquid salt of copper precipitates metallic copper.

Ferrocyanate of potassa is also an excellent test of the presence of copper; it produces a brown cloud in solutions containing the peroxide.* (1232)

SECTION XIV. *Lead.*

To obtain pure lead.

1243. THE natural compounds of this metal are very numerous. The most important is the sulphuret, from which the pure metal is chiefly procured. Lead is also found combined with carbonic, sulphuric, phosphoric, arsenic, molybdic, and chromic acids, and with oxygen and chlorine. To obtain lead perfectly pure, Berzelius dissolved it in nitric acid, and crystallized the salt several times, till the mother liquor, on adding carbonate of ammonia, gave no traces of copper. The pure nitrate of lead, mixed with charcoal, was strongly heated in a essian crucible; and the lead, which separated, was kept for ome time in fusion, in order to free it entirely from charcoal. he lead, thus obtained, when re-dissolved in nitric acid, gave o trace of any other metal.

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* The oxidation of copper plates is a matter of very great importance in the arts, and in the case of great and expensive works where few impressions of an engraving are taken and the plates laid aside for a considerable length of time, a serious injury to the plates is sustained by the necessity of cleaning them from oxide, when they are to be again used. This may be prevented by varnishing the pl with common lac varnish, which can easily be removed, when requisite, by spirit of wine. Brewster's Jour. i. 76. Bost. Jour. ii. 206.

Properties. 1244. Lead appears to have been known in the earliest ages f the world. Its colour is bluish white. It melts at 600°, and y the united action of heat and air is readily converted into n oxide, its specific gravity is 11,4. At common temperatures undergoes little change by mere exposure to air, but it is owly corroded by the joint agency of air and water; hence the anger of leaden pipes and vessels for containing water, which intended to be drunk. Water appears also to act more eadily on lead, when impregnated with the neutral salts that are ccasionally present in spring water.* Exposed upon ignited harcoal to a current of oxygen gas, it burns with a blue flame, hrowing off dense yellow fumes of oxide. The alchymists ave this metal the name of *Saturn*.

Oxides. 1245. *Oxides of Lead.* There are three oxides of lead. he *protoxide* is the basis of the salts; it may be obtained pure y heating the nitrate of lead to redness in a vessel with a small rifice, till the whole of the acid is expelled. It is insipid and nsoluble in water, of a pale yellow colour, and, when fused, rystallizes on cooling in irregular scales. It is volatile at a right red heat. It is very soluble in solutions of potassa and oda; and when in fusion, it readily dissolves several of the arthy bodies, and of the common metallic oxides. If it be onsidered as a protoxide, consisting of one proportional of lead nd one of oxygen, then the number 104 (deduced from the mean of the best analyses) will represent lead, and it will conist of 104 lead + 8 oxygen. This oxide is known in commerce under the name of *massicot;* or when vitrified, as btained by calcining lead upon a large scale, it is called *litharge*. Massicot.

When melted lead is exposed for some time to the air, it ecomes incrusted with a grey pellicle, which, on removal, is ucceeded by another and so on until the whole is converted nto a greenish grey powder, consisting of a mixture of the prooxide with metallic lead.

Minium 1246. If the protoxide be exposed to heat and oxygen, it gradually acquires a bright red colour, and is known under the ame of *minium* or *deutoxide* of lead. This oxide, when exposed to nitric acid, is resolved into protoxide, which is dissolved, and into *peroxide*, which is an insoluble brown substance, onsisting of 104 lead + 16 oxygen. When peroxide of lead is eated it gives out half its oxygen and becomes yellow prooxide.

Minium affords, on analysis 104 lead + 12 oxygen, and may, therefore, be regarded as a definite compound of the prooxide and peroxide.

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* On the presence of lead in water, consult Dr Lambe's "Researches respecting Spring Water" vo. Lond. Johnson) and also Guyton, 26 Nich. Jour. 102.

The minium or *red lead* of commerce generally contains a proportion of protoxide and of sulphate, with traces of chloride of lead and silica. To succeed in obtaining it of a fine red tint, it requires to be manufactured in quantities, and with several precautions. The method employed in Derbyshire is described in WATSON's *Chemical Essays*, Vol. iii. p. 338.

1247. The oxides of lead are easily vitrified, and have the property of uniting with all the metals except gold and silver. Hence gold or silver may be purified by melting them with lead. See (1256.)

Oils dissolve the oxide of lead, and become thick and consistent; in which state they are used as the basis of plasters, cements for water-works, paints, &c.

Chlorides. 1248. *Lead and Chlorine,—Chloride of Lead.* When 30 grains of lead reduced to fine filings, are thrown into 60 cubic

Exp. inches of chlorine gas, moderately warmed, the metal burns with a clear white flame accompanied with sparks.* The combination of lead and chlorine may, however, be more easily effected, by precipitating the nitrate or any soluble salt of lead with a solution of common salt, and washing the precipitate with a sufficient quantity of water. H. 2. 105.

The same substance is obtained by adding muriatic acid to nitrate of lead; it is white and fusible, and on cooling forms a hornlike substance (*plumbum corneum.*) It volatilizes at a high temperature. It dissolves in 22 parts of water at 60°; is more soluble in boiling water, separating, as the solution cools, in small acicular crystals, unchanged by exposure to air, and of a sweetish taste. It dissolves in dilute nitric acid. It has been analyzed by Berzelius, who states it to consist of 100 muriatic acid + 409,06 protoxide of lead, equivalent to 380,06 metallic lead + 129 chlorine. Dr J. Davy found it to be composed of

Chlorine	25,78	34,75	36
Lead	74,22	100,	104
	100,		140

It is the only compound of chlorine and lead that is known and is constituted of 1 atom of each of its elements. H.

1249. When two parts of the red oxide of lead are made into a paste with one of muriate of soda, and water added occasionally as the mixture hardens, soda is disengaged, and a *subchloride* of lead is formed mixed with oxide of lead. This, on fusion, affords the fine yellow pigment called *mineral or patent*

Patent yellow. *yellow.* The disengaged soda attracts carbonic acid from the atmosphere, but not enough to convert it into a carbonate. In the large way, it is found necessary to supply carbonic acid to the soda thus formed, by burning it with saw-dust. By this process a large quantity of soda was extracted from common salt till cheaper methods were discovered. H. 2. 106. When treated by nitric acid, it forms nitrate of lead and a portion of chlorine separates.

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* Or laminated lead may be heated in chlorine, which will be absorbed and chloride of lead will result. B.

Chlorate.

1250. *Chlorate of Lead* is obtained by digesting the protoxide in chloric acid; it separates by slow evaporation, in white crystalline flakes of a very sweet taste. When heated it gives out oxygen and becomes a chloride.

Iodide.

1251. *Iodide of Lead,* formed by heating leaf-lead with iodine, is a yellow insoluble compound. It is also formed by adding hydriodic acid or hydriodate of potassa to solution of nitrate of lead. It consists of 1 atom of iodine and 1 of lead.*

Nitrate.

1252. *Nitrate of Lead* is obtained by dissolving the metal, not in excess, in dilute nitric acid, and evaporation. The salt crystallizes in tetraëdra and octoëdra, which are white translucent, and of a styptic taste. It is soluble in 8 parts of water at 212°. It consists of 112 oxide of lead + 54 nitric acid. The alkalies throw down protoxide of lead from the solution of this salt.

Subnitrate.

1253. *Subnitrate of Lead* may be formed by boiling a mixture of equal weights of nitrate and protoxide of lead in water, filtering while hot, and setting it by to crystallize; it forms pearly crystals, of a sweet astringent taste. (CHEVREUIL, *Annales de Chimie,* lxxxii.) It consists of two proportionals oxide = 224, + one proportional nitric acid = 54.

1254. Chevreuil and Berzelius have described three *nitrites* of lead, but their composition appears doubtful. (*Ann. de Chim.* lxxxiii. and lxxxviii.) A detailed account of them is given by Dr Thomson.—*System,* ii. 578.

Sulphuret.

1255. *Sulphuret of Lead* may be formed artificially by fusion. Its lustre and colour much resemble pure lead, but it is brittle: it consists of 104 lead + 16 sulphur.

1256. *Native Sulphuret of Lead,* or *Galena,* is the principal source of the vast commercial demands of the metal. It occurs massive and crystallized, particularly in limestone rocks. Its primitive form is the cube, of which there are several modifications, and among them the octoëdron. It often contains traces of silver, and sometimes in such quantity as to render it worth separating, which is effected by exposing the roasted sulphuret to the action of heat and air in shallow earthen dishes; the lead becomes oxidized and converted into litharge, while the silver is left pure, in consequence of its power of resisting the influence of heat and air. This process is called *cupellation.* The litharge is afterwards reduced by fusion with charcoal.†

Cupellation.

The reduction of galena upon a large scale is a sufficiently simple process. The picked ore, after having been broken and washed, is roasted in a reverberatory fire, the temperature being such as to soften but not fuse it. During this operation it is raked till the fumes of sulphur are dissipated, when it is brought into perfect fusion; the lead sinks to the bottom, and is run out into oblong moulds called *pigs;* the scoriæ are again melted, and furnish a portion of less pure metal.

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* An insoluble *Iodate of Lead* is thrown down on adding iodate of potassa to any of the soluble salts of lead.

† The quantity of lead required for silver of various degrees of fineness may be learned from a memoir of D'Arcet in the first volume of Annales de Chim. et de Phys.

The mines of Great Britain afford an annual produce of about 48000 tons of smelted lead, of which nearly the whole is obtained from the sulphuret.

Hyposulphite. 1257. *Hyposulphite of Lead* is precipitated in the form of a white powder, nearly insoluble in water, by adding solution of nitrate of lead to hyposulphite of potassa. It is composed, according to Herschel, of 70,30 protoxide of lead + 29,70 hyposulphurous acid. These numbers correspond to 1 proportional of oxide of lead = 112 + 2 proportionals of hyposulphurous acid = 48.

Sulphite. 1258. *Sulphite of Lead* may be obtained by digesting yellow oxide of lead in sulphurous acid; or by adding sulphurous acid or sulphite of potassa to nitrate of lead. It is white, insoluble, and tasteless, and consists of one proportional of each of its components; namely, 32 sulphurous acid + 112 oxide of lead. When heated it loses sulphurous acid.

Sulphate. 1259. *Sulphate of Lead.* When metallic lead is boiled in concentrated sulphuric acid, sulphurous acid is evolved, and a white sulphate of lead is formed. It is so nearly insoluble, that it may be formed by adding dilute sulphuric acid, or an alkaline sulphate, to a solution of nitrate of lead. Dr Thomson found, that after having been dried at a temperature of 400°, it might be heated to redness in a platinum crucible without losing weight. Heated on charcoal by the blowpipe, it is decomposed and reduced. It consists of one proportional of sulphuric acid = 40, and one proportional of oxide of lead = 112; and its representative number is therefore 152. Sulphate of lead is insoluble in alcohol and in nitric acid: it is sparingly soluble in dilute sulphuric acid, and separates from it in small prismatic crystals.

The insolubility of lead in sulphuric acid occasions its being employed as the material for constructing the chambers in which that acid is prepared, and even for boiling down the weak acid. (529). H.

Tests of lead. 1260. All the solutions of lead are decomposed by sulphuretted hydrogen and by alkaline hydro-sulphurets, and a hydrosulphuretted oxide is thrown down. Hence these compounds are excellent tests of the presence of lead in wine or any other liquor, discovering it by a dark coloured precipitate.* Hence, also, characters traced with solution of acetate of lead, become legible when exposed to sulphuretted hydrogen gas. The same

Exp.

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* Or, subcarbonate of ammonia, which is a very delicate test, may be employed to precipitate the lead in a state of white carbonate, which, on being washed and digested with sulphuretted hydrogen water, will instantly become black. U.

property explains, too, the effect of alkaline hydro-sulphurets in blackening the glass bottles, in which they are kept. The effect is owing to the action of sulphuretted hydrogen on the oxide of lead, which all the white glass contains. H. 2. 10.*

Phosphate.

1261. *Phosphate of Lead* is formed by mixing solutions of nitrate of lead and phosphate of soda, or phosphoric acid. It is yellowish white; insoluble in water; soluble in alkaline solutions, and in nitric acid. It is decomposed by sulphuric acid, and by hot muriatic acid. It fuses before the blowpipe, and crystallizes on cooling. It consists of 112 oxide of lead + 28 phosphoric acid = 140.†

Carbonate.

1262. *Carbonate of Lead.*—When an alkaline carbonate is added to nitrate of lead, a white precipitate of carbonate of lead falls: it is tasteless, insoluble in water, but soluble in fixed alkaline solutions. It is employed as a white paint, under the name of *white lead* or *ceruse*, and is usually prepared by exposing sheet lead to the action of the vapour of vinegar. The process is described in Aikin's *Dictionary* (*Art.* Lead.) It consists of 112 oxide of lead + 22 carbonic acid = 134 carbonate of lead.

1263. *Borate of Lead* is precipitated in the form of a white powder, when borate of soda is mixed with nitrate of lead.

Characters of the salts of lead.

1264. The soluble salts of lead have a sweetish austere taste, and are characterized by the white precipitate produced by ferrocyanate of potassa, the deep brown by hydrosulphuret of ammonia, and the yellow by hydriodate of potassa.

1265. The salts insoluble in water are dissolved by soda and potassa, and by nitric acid, when the metal is rendered manifest by sulphuretted hydrogen and other tests. Heated by the blow-pipe upon charcoal they afford a button of metal.

Alloys.

1266. *The Alloys of Lead* with the preceding metals are not important, if we except that which it forms with tin. Common *pewter* consists of about 80 parts of tin and 20 of lead. Equal parts of lead and tin constitute *plumber's solder;* and what is termed *pot-metal* is an alloy of lead and copper.

Analysis of.

1267. In analyzing these alloys, 100 grains in filings may be boiled to dryness in two ounces of nitric acid, water poured upon the residue, and filtered; the peroxide of tin remains on the filter, and the nitrate of lead, which passes through in solution, may be converted into sulphate by adding sulphate of soda. 152 grains of sulphate of lead dried at a red heat, indicate 104 of metal; and 75 grains of washed peroxide of tin are equivalent to 59 grains of metallic tin.

1268. With potassium lead forms a brittle and very fusible alloy; with sodium the compound is equally brittle but less fusible. When exposed to air these alloys suffer decomposition in consequence of the oxidizement of the alkaline bases. The alloy of lead and manganese has not been examined. When lead is fused with iron, two alloys are obtained; that at the bottom of the crucible consisting of lead with a little iron; while the superficial portion is iron with a little lead (GUYTON MORVEAU, *Ann. de Chim.* lvii.) With zinc, lead forms a hard ductile alloy.

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* *Phosphuret of Lead* may be formed by dropping phosphorus into melted lead. It is of the colour of lead, and soon tarnishes. *Hypophosphite of Lead* has not been examined. *Phosphite of Lead* was prepared by Berzelius by mixing muriate of lead with phosphite of ammonia. It is white, tasteless, and insoluble, and appears to consist of 1 proportional of oxide of lead = 112 + 1 proportional of phosphorous acid = 20.

† Ann. Philos. 1. 12.

1269. If lead be heated so as to boil and smoke, it soon dissolves pieces of copper thrown into it; the mixture, when cold, is brittle. The union of these two metals is remarkably slight; for, upon exposing the mass to a heat no greater than that in which lead melts, the lead almost entirely runs off by itself. This process is called *eliquation*. The coarser sorts of lead, which owe their brittleness and granulated texture to an admixture of copper, throw it up to the surface on being melted by a small heat. U. 544.

Eliquation.

SECTION XV. *Antimony.*

Ores.

1270. THIS metal is found *native* in Sweden, in France, and in the Hartz; but its principal ore is the *sulphuret* which is found massive and crystallized, and of which there are several varieties. The most common is the *radiated*, which is of a grey colour, brittle, and frequently crystallized in four and six-sided prisms. This ore may be decomposed, and the pure metal obtained from it, by the following process: Mix three parts of the powdered sulphuret with two of crude tartar, and throw the mixture by spoonfulls into a red-hot crucible; then heat the mass to redness, and a button will be found at the bottom of the crucible, which is the metal as it commonly occurs in commerce, and is nearly pure. Reduce this button to fine powder, and dissolve it in nitro-muriatic acid; pour this solution into water, which will occasion the precipitation of a white powder, which is to be washed and mixed with twice its weight of tartar and exposed to a dull red heat in a crucible. The button now obtained is pure antimony.

Reduction of.

Or, two parts of the sulphuret may be fused in a covered crucible with one of iron filings, and to these when in fusion, half a part of nitre may be added. The sulphur quits the antimony and combines with the iron. H.

1271. Antimony is of a silvery white colour, brittle, and crystalline in its ordinary texture. It fuses at about 800°, and is volatile at a high heat. Its specific gravity is 6,70 (HATCHETT, *Philos. Trans.* 1803.) (6,424 T.) Placed upon ignited charcoal, under a current of oxygen gas, antimony burns with great brilliancy, throwing off its oxide in the form of a dense yellow smoke.

Properties.

1272. *Antimony and Oxygen.* These bodies form two well-defined compounds, the history of which is of great importance to the pharmaceutical chemist.

Protoxide. The *Protoxide of Antimony* is thus obtained: To 200 parts of sulphuric acid add 50 parts of powdered metallic antimony. Boil the mixture to dryness, wash the dry mass, first in water, and then with a weak solution of carbonate of potassa; a white powder remains, which when thoroughly washed with hot water, is protoxide of antimony. It may also be procured by dissolving antimony in muriatic acid, pouring the solution into water, and washing the white precipitate with weak solution of potassa.

1273. This oxide may also be obtained by adding ammonia to solution of tartrate of antimony and potassa, heating the mixture and washing the precipitate in large quantities of boiling water. It is thus procured in the form of a heavy white powder.

This protoxide exists in all the active antimonial preparations; in emetic tartar, kermes, glass of antimony, golden sulphuret, &c. It is fusible and volatile at a red heat: decomposed by sulphur and charcoal, and when acted on by nitric acid, is converted into peroxide. If heated with chlorate of potassa it deflagrates and also becomes peroxidized; it is very soluble in muriatic acid, and readily forms emetic tartar when boiled in solution of tartrate of potassa.

1274. When metallic antimony in fusion is exposed to a bright red heat, it is converted into an oxide which appears to be the protoxide, and which condenses in long and delicate needles when sublimed. It was formerly called *argentine flowers of antimony.*

decomposes water. The vapour of water, brought into contact with ignited antimony, is decomposed with so much rapidity as to produce a series of detonations. H. 2. 67.

Peroxide, how obtained. 1275. *Peroxide of Antimony* is procured by acting for a considerable time upon the powdered metal, by excess of hot nitric acid, and exposing the product to a red heat, to expel the redundant acid. The *diaphoretic antimony* and *Bezoar mineral* of old Pharmacopœiæ, consisted of this oxide, which, compared with the protoxide, is nearly inert.

Another process. 1276. Peroxide of antimony is also formed by exposing the metal or the protoxide mixed with five or six parts of nitre to a red heat in a porcelain crucible, and washing the residue with hot water.* It is yellowish white, but becomes buff-coloured when heated, and returns to its former tint on cooling. It neither fuses nor volatilizes at a bright red heat, but when exposed to the flame of a spirit-lamp urged by a blow-pipe, it passes off slowly in white fumes, being partially reduced by the hydrogen of the flame.

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* Or by projecting powdered metallic antimony into red-hot nitre. H.

Composition of the oxides.

1277. The two oxides are composed, according to Proust, as follows:

The first of 100 antimony + 22,7 oxygen.
The second of 100 antimony + 30, oxygen.

Four oxides of Berzelius.

1278. Berzelius has described four compounds of antimony,[*] which are said to be constituted as follows:

1	Suboxide consisting of	100 antimony	+ 4,65 oxygen.
2	Oxidule	100	+ 18,60 . . . .
3	White oxide	100	+ 27,90 . . . .
4	Yellow oxide	100	+ 37,20 . . . .

The first, obtained by a long exposure of the metal to a humid atmosphere, or by making that metal the positive conductor in a galvanic arrangement, cannot be considered as a definite compound. The next, is the true *protoxide* and may be obtained as already described. (1272) This oxide fuses at a red heat, and on cooling becomes an almost white mass resembling asbestus. It appears to be the only oxide which is capable of acting as a true base with acids, and is that which gives activity to the principal medicinal preparations of antimony. The third, or *white oxide* was formed by Berzelius by the action of nitric acid; or by dissolving the metal in nitro-muriatic acid, decomposing by water, washing the precipitate, and calcining it in a platinum crucible. The fourth or *yellow oxide* was obtained by fusing antimony with nitre. (1276).

Dr Thomson's method.

Dr Thomson obtained it more simply by dissolving antimony in nitric acid, evaporating to dryness, and exposing the product for some hours to a heat of 500° F. A yellow powder remained, of which 7½ parts, exposed to heat, left 7 of white deutoxide; and 100 grains by distillation gave very nearly 19 cubic inches of oxygen gas.[†] H. 2. 69.

Atomic composition not satisfactorily established.

1279. The atomic composition of these bodies is by no means satisfactorily established. Proust,[‡] Berzelius,[§] and Dr Thomson have given different views regarding it; that, however furnished by the last mentioned chemist is more consistent, Dr Henry thinks, with the general law of chemical combination and would give 44 as the equivalent number for antimony. Till its composition is decided we may, he conceives, assume that number and consider the protoxide as constituted of one atom of metal and one of oxygen (44 + 8) = 52; the deutoxide of one and one half (44 + 12) = 56, and the peroxide of one and two (44 + 16) = 60. We have here, however, with regard to the deutoxide, the anomaly of the multiple of the oxygen of the first oxide being 1½ instead of an entire number.[‖]

Antimonious and antimonic acids.

1280. The deutoxide and peroxide of antimony ought strictly, indeed, to be arranged among acids, rather than among oxides; for each of them combines with salifiable bases, and affords a class of salts. The first has been called the *antimonious* acid, and its compounds *antimonites;* the second the *antimonic* acid, and the salts which it composes *antimoniates.** H. 2. 70. The acid properties of peroxide of antimony were long since remarked by Thenard, (*Ann. de Chim.* xxxviii. and xli.) and the subject has lately been investigated by Berzelius, who obtained it by exposing a mixture of one part of powdered antimony and six of nitre to a red heat in a silver crucible for an hour. After washing off the soluble matters by cold water, and digesting the white powder which remains, in muriatic acid, washing and drying it at a red heat, it is pure *antimonic acid,* and consists of antimony 100, oxygen 37,2.

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[*] Ann. de Chim. lxviii. 225.

[†] First Principles, ii. 41.

[‡] Jour. de Phys. iv.

[§] Ann. de Chim.

[‖] Dr John Davy's researches on the composition of the chlorides, (*Phil. Trans.* 1812,) give the number 42,5 as the representative of antimony; and this nearly agrees with Mr Brande's experiments upon the composition of the protoxide, (obtained by precipitation from emetic tartar), which give 45 and which he has adopted.

Berzelius's process.

Chloride.

1281. *Antimony and Chlorine* combine in one proportion only to produce the *chloride of antimony.* The powdered metal takes fire when thrown into the gas, and a compound, at first liquid, but afterwards concreting, is formed. It may also be produced by the distillation of one part of powdered antimony with two and a half of bi-chloride of mercury (corrosive sublimate;) or by dissolving the protoxide of antimony in muriatic acid, and evaporating to dryness. The pure chloride is a soft solid at common temperatures, but becomes liquid by a gentle heat, and crystallizes as it cools. It is the *butter of antimony* of old writers. It deliquesces by exposure to air; and is a powerful caustic. When water is added to the chloride of antimony, a mutual decomposition ensues and hydrated protoxide of antimony, formerly called *Algarotti's powder,* or *mercurius vitæ,* and muriatic acid result.

The chloride of antimony probably consists of one atom of each constituent.†

Action of nitric acid,

1282. Nitric acid acts powerfully on metallic antimony, and if mixed with it in fine powder, will sometimes cause its inflammation. The metal becomes peroxidized, and scarcely an appreciable portion is retained in solution. As in some other cases of the vehement decomposition of nitric acid, ammonia is produced, (472) which may be rendered sensible by pouring potassa on the white magma that results.

Protoxide of antimony, digested in dilute nitric acid, produces a difficultly soluble salt, which separates in white scaly crystals, and which appears to be a *nitrate of antimony.*

—of nitro-muriatic.

1283. Nitro-muriatic acid readily dissolves antimony, and forms an orange-coloured solution, which is decomposed by the addition of water. Iron or zinc immersed in this solution throws down a black powder, which, according to Thenard, is pyrophoric.

Sulphuret.

1284. *Sulphuret of Antimony* is easily formed by fusing the metal with sulphur. This artificial sulphuret, exactly resembles the native compound which last may be employed on account of its cheapness, for exhibiting the properties of sulphuret of antimony. The proportions of its ingredients, as stated by Berzelius, differ from those assigned by Proust, viz.

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* Berzelius has called them *stibious* and *stibic* acids, from the Latin *stibium.*

† *Iodide of Antimony* is of a dark red colour; acted upon by water, it produces hydriodic acid and xide of antimony.

Antimony	72,86	100,	270
Sulphur	27,14	37,25	100
	100		

Dr Thomson makes it to consist of 77$\frac{1}{3}$ metal + 26$\frac{2}{3}$ sulphur, or of 100 metal + 34,4 sulphur. To be double the oxygen of the protoxide, the sulphur ought to be 36,4 to 100 of the metal. H. 2. 72.

Glass of antimony.

1285. When the native sulphuret (*crude antimony*) is exposed under a muffle to a dull red heat, it gradually loses sulphur and absorbs oxygen, being converted into a grey powder, which consists of a mixture of protoxide of antimony and sulphuret. If the heat be increased, this fuses into a transparent substance of a yellow or brown colour, formerly called *glass of antimony*. Its composition is variable; it generally contains about 85 *per cent.* of protoxide and 15 of sulphuret. In that which is imported for pharmaceutical purposes, from Germany and Holland, there is usually a portion of siliceous earth, and it is sometimes adulterated with the oxide of lead. This fraud is easily detected by digesting the finely powdered glass in hot nitric acid, diluting the solution and filtering. The filtered liquor gives a white precipitate on the addition of sulphate of soda if lead were present.

During the formation of glass of antimony, if the heat be raised too high the greater part of the protoxide sublimes in slender crystalline needles; while another portion, if air be not excluded, passes into the state of peroxide, and undergoes no change at a very high temperature.

1286. Eight parts of oxide and two of sulphuret give an opaque compound, of a red colour inclining to yellow; and called *crocus metallorum*. With eight parts of oxide and four of sulphur, we obtain an opaque mass of a dark red colour, called *liver of antimony*. In these compounds the oxide is at its minimum of oxidation; for the peroxide is incapable of dissolving the sulphuret.* H.

Kermes mineral.

1287. *Hydrosulphuretted Oxide of Antimony.*—This compound has long been known under the name of *kermes mineral;* it is commonly prepared as follows: Equal parts of sulphuret of antimony and common potash are fused together; the resulting mass is finely powdered and boiled in ten times its weight of water. The liquor is filtered while hot; and, during cooling, it deposits *kermes*. The mother liquor of kermes deposits a copious yellowish red precipitate upon the addition of dilute sulphuric acid, which, when washed and dried, is known under the name of *golden sulphur of antimony.* In the *U. S. Pharmacopœia* it is called *antimonii sulphuretum præcipitatum.*

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* *Sulphate of Antimony.*—When sulphuric acid is boiled upon finely-powdered antimony, the metal is oxidized, and an acid *sulphate* and *subsulphate* of *antimony* are the results. In both these salts the metal is in the state of protoxide.

Theory of the process. In forming these compounds, the following changes seem to have taken place. The sulphuret of antimony and potassa act upon the water, a portion of which is decomposed; hydrogen is transferred to the alkaline sulphuret, to form hydrosulphuret of potassa; hydrogen and oxygen unite to the sulphuret of antimony, producing a hydrosulphuretted oxide of that metal (*kermes*), which remains dissolved in the hot alkaline hydrosulphuret, and of which one portion is precipitated as that solution cools. When dilute sulphuric acid is added, the hydrosulphuret of potassa is decomposed, sulphate of potassa is formed, and sulphur and sulphuretted hydrogen are liberated; the sulphur falls in combination with the *kermes*, producing the *golden sulphur*, or sulphuretted hydrosulphuret.

1288. When the sulphuret of antimony is detonated with twice its weight, or upwards, of powdered nitre, the sulphur is oxygenated by the oxygen of the nitric acid; sulphate of potassa is formed, and an oxide of antimony is obtained, varying in its degree of oxidation, with the proportion of nitre which has been employed. The oxide remains, after washing away the sulphate with boiling water. If four times its weight of nitre be employed, the metal gains 32 per cent. of oxygen; acquires the characters of an acid; and forms, with potassa, a crystallizable compound, or *antimoniate.* H. 2. 73. Antimoniates.

1289. *Antimoniate of Potassa* dissolves in hot water, and this solution produces precipitates of insoluble antimoniates in several other metallic solutions.

1290. *Antimoniate of Ammonia* is formed by digesting the acid in ammonia. On evaporation a *superantimoniate of ammonia* is obtained in the form of a white powder.*

1291. *Phosphuret of Antimony* is formed by heating together equal parts of oxide of Antimony, phosphoric acid, and charcoal. It is white and brittle. Phosphuret.

1292. *Phosphate of Antimony* has not been formed: in the *U. S. Pharmacopœia* there is a preparation called *pulvis antimonialis*, formed by heating one part of sulphuret of antimony with two of hartshorn shavings. The action of heat upon the sulphuret has already been described. (1285.) Its effect upon the hartshorn shavings is to destroy the animal matter, leaving little else than phosphate of lime. So that the *pulvis antimonialis* consists essentially of protoxide of antimony, mixed with phosphate of lime. This preparation is usually considered analogous to, if not identical with, *James's Powder*, which, Phosphate. James's powder.

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* Our knowledge of the composition and properties of the oxides of antimony, and of most of their combinations, is still extremely imperfect, and the whole subject requires further investigation before the anomalies that now present themselves can be cleared up. B.

according to Dr Pearson's analysis (*Phil. Trans.* 1791), consists of 43 phosphate of lime, and 57 oxide of antimony.[*]

Mr Brande's experiments on.

1293. In examining Antimonial Powder from various sources, prepared according to the directions of the *Pharmacopœia*, Mr Brande has found it of very variable composition: sometimes it contains peroxide of antimony only; sometimes there is a proportion of protoxide, and in some few cases the powder has consisted chiefly of bone-earth. These differences are referable to the mode of preparing it, but in almost every case, a very large proportion of the protoxide is lost during the process, and he found it a matter of great difficulty so to conduct it as to obtain, upon the large scale, an uniform product. For medical use he considers emetic tartar as the only certain and necessary preparation of antimony; if, however, a compound of the nature of the Antimonial powder be requisite, one of the best modes of preparing it would be to dissolve certain proportions of protoxide of antimony and phosphate of lime in muriatic acid, precipitate by ammonia, and edulcorate with a large quantity of water. Mr Chenevix advises for this purpose equal parts of the oxide and phosphate, but such proportion of antimony is too great: Mr Brande has made a useful Antimonial Powder by dissolving 200 grains of bone-earth and 100 of protoxide of antimony in a measured ounce and a half of muriatic acid, and pouring the solution into a weak solution of ammonia; the precipitate, when washed, dried, and reduced to a fine powder, weighed 280 grains.

Mode of preparing antimonial powder.

1294. The following method furnishes, in the dry way, a tolerably uniform Antimonial Powder: Burn two pounds of hartshorn to a cinder, reduce it to powder, and heat it to a dull redness in an iron pot: then gradually stir into it one pound of powdered sulphuret of antimony, added in successive portions, and continue the same heat as long as fumes arise; when these cease the mixture will have a dirty grey colour, and during the operation small crystals of protoxide of antimony will be seen to collect upon its surface when a portion is taken out in an iron spoon. In this grey state it should be put into a crucible and heated to intense redness; a phosphorescent light of a greenish tint is soon perceived, and when this ceases the crucible may be removed from the fire, and its contents when cold reduced to a fine powder, which should be perfectly white.

1295. The solutions of antimony afford orange-coloured precipitates with sulphuretted hydrogen, and those which are acid are precipitated when largely diluted with water.

Alloys.

1296. Antimony forms brittle alloys with the malleable metals. When gold was alloyed with $\frac{1}{1920}$ its weight of antimony, the compound was perfectly brittle; and even the fumes of antimony in the vicinity of melted gold are sufficient to destroy its ductility. (Hatchett, *Phil. Trans.* 1803.) With potassium and sodium it forms white, brittle compounds, destructible by the action of air and water.

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[*] Different formulæ have been given for imitating *James's Powder*, the real recipe having been studiously concealed and a false one published in its stead; that of Dr Pearson furnishes a mere mixture of oxide of antimony with phosphate of lime. Dr Ure has given a copy of the original specification lodged in Chancery. See *Ure's Dictionary*, p. 175.

Its alloys with manganese and with zinc have not been examined.

Type Metal.

Alloyed with lead in the proportion of 1 to 16, and a small addition of copper, antimony forms the alloy used for *printers' types*. With lead only, a white and rather brittle compound is formed, used for the plates upon which music is engraved. With iron it forms a hard whitish alloy, formerly called *martial regulus*, which may be obtained by fusing two parts of sulphuret of antimony with one of iron filings; a scoria consisting chiefly of sulphuret of iron is formed, and the fused alloy beneath usually presents a stellated appearance in consequence of its crystallization. This star was much admired by the alchymists, who considered it a mysterious guide to transmutation. With tin antimony constitutes a kind of *pewter*, a term however which has also been applied to some other alloys, especially that of lead and tin. (1266.) The finest pewter consists of about 12 parts of tin and 1 of antimony, with a small addition of copper. A good white metal, used for teapots, is composed of 100 tin, 8 antimony, 2 bismuth, and 2 copper.

Analysis of Alloys of Antimony, &c.

1297. The analysis of an alloy of tin, lead, copper, and antimony, may be thus performed: introduce 100 grains into a matrass with a wide mouth, and pour upon it one ounce of water and two of nitric acid; digest and evaporate to dryness. The dry mass will consist of the nitrates of lead and copper, which are soluble, and may be taken up by two ounces of hot water, and of the peroxides of tin and antimony, which are insoluble, and remain upon the filter.

To the solution of the nitrates add sulphate of soda, which throws down sulphate of lead, and which is to be collected in a filter, washed, dried at a red heat, and weighed. (1259.) The filtered liquor may be evaporated to about two ounces in bulk, and having rendered it slightly acid by dilute sulphuric acid, immerse in it a plate of iron, which will throw down metallic copper, to be purified if requisite (1259), dried, and weighed.

The separation of the peroxides of tin and antimony is attended with many difficulties; it may be imperfectly effected by solution in nitro-muriatic acid, and subsequent dilution with a large quantity of water, which throws down the antimonial oxide, not however pure, but with a portion of peroxide of tin: the latter, retaining a little peroxide of antimony, may be procured by evaporation and exposure of the residue to a dull red heat in a porcelain cup.

1298. In analyzing compounds of tin and antimony, it is necessary first to make an alloy, in which the antimony shall not exceed the proportion of $\frac{1}{12}$th part, for then concentrated muriatic acid, by digestion with this alloy, dissolves the tin, and leaves the antimony untouched; but if more than $\frac{1}{25}$th part of antimony enters into the combination, the tin acquires the insolubility of that metal in muriatic acid. H. 2. 74.

Section XVI. *Bismuth.*

Native.

1299. This metal is found native; combined with oxygen; and with arsenic and sulphur. *Native Bismuth* occurs crystallized in octoëdra and cubes, and in addition to arsenic generally contains cobalt.

Process for obtaining crystals.

1300. Bismuth may be obtained in regular crystals, by fusing a quantity of it in a crucible, and allowing it to cool till a crust is formed on the surface, the extremity of the crucible may then be broken off and the fluid metal beneath be allowed to escape. The under surface of the crust will be found beautifully crystallized.

Properties.

1301. Bismuth has a reddish white colour, and is composed of broad brilliant plates adhering to each other. Its specific gravity is 9,822, but is increased by hammering. It breaks, however, under the hammer, and hence cannot be considered as malleable; nor can it be drawn out into wire. The bismuth of commerce is not quite pure. To purify it, Dr Thomson dissolved it in nitric acid, decomposed the nitrate by water, edulcorated the oxide, and reduced it to a metallic state by heating it in a covered crucible with black flux.[*]

1302. Bismuth is one of the most fusible metals, melting at 476° Fahrenheit; and it forms, more readily than most other metals, distinct crystals by slow cooling.

Oxide.

1303. When bismuth is exposed to heat and air it oxidizes, forming a fusible *white oxide.* If the heat be increased by directing a current of oxygen upon the metal, it burns with much brilliancy, and produces an abundant yellow smoke, which condenses in the form of a yellowish white sublimate. When in fusion this oxide acts upon other oxides much in the same way as oxide of lead.—It is the only oxide of bismuth with which we are acquainted; and consists, according to the experiments of Lagerhjelm, of

Bismuth	89,863	100	71
Oxygen	10,137	11,28	8
	100		79

From this result, which makes the equivalent number of bismuth 71,[†] and that of the oxide 79,[‡] Dr Thomson's estimate, founded on his own experiments, does not materially differ. This oxide occurs, though very rarely, *native:* it has been found in Cornwall and Saxony. H.

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[*] (Ann. of Phil. N. S. ii. 122.)

[†] 72 T.

[‡] 80 T.

Chloride.

1304. *Chloride of Bismuth*, is procured by heating the metal in the gas, or by evaporating the muriate to dryness and submitting the residue to distillation, when the chloride sublimes, and afterwards deliquesces into what was called *butter of bismuth.* A similar product is obtained by introducing finely divided bismuth into chlorine gas, when the metal takes fire and burns with a pale blue light. This compound is the only known *chloride of bismuth.* Exp.

1305. It was analyzed by Dr Davy, and found to contain

Bismuth	66.4	100
Chlorine	33.6	50.6
	100.	

From this analysis, the equivalent of bismuth, also, appears to be 71, agreeing with the number derived from the oxide. H.

Iodide.

1306. *Iodide of Bismuth*, obtained by heating iodine with the metal, is of an orange-colour, and insoluble in water. When hydriodic acid or hydriodate of potassa is added to nitrate of bismuth, a precipitate falls of a deep chocolate-brown colour, insoluble in water but soluble in liquid potassa.*

Nitrate.

1307. *Nitrate of Bismuth.*—Nitric acid dissolves bismuth with great rapidity. To one part and a half of nitric acid, add, at distant intervals, one of bismuth, broken into small pieces. The solution is crystallizable in small four-sided prisms.

1308. The Nitrate of Bismuth consists of 1 proportion of oxide + 1 of acid.

1309. Nitrate of Bismuth is decomposed by water, and the oxide of bismuth is thrown down in the form of a fine white powder, called *magistery of bismuth, pearl white*, or *blanc de fard.* In this state it has been used in medicine as a tonic.† —*Quarterly Journal*, viii. 295.

Exp.

1310. If characters be written on paper with nitrate of bismuth they are invisible when dry, but become white and legible on immersion in water, thus forming a *white sympathetic ink.* The same characters are rendered brown or black by solution of sulphuretted hydrogen.

Sulphuret.

1311. *Sulphuret of Bismuth.*—Bismuth combines with sulphur, and forms a bluish grey sulphuret, having a metallic lustre, which is, also, found native. Lagerhjelm has analyzed it, and found it to consist of

Bismuth	81.619	100	71
Sulphur	18.381	22.52	16
	100.		87‡

H. 2. 86.

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* *Iodate of Bismuth* is thrown down upon adding Iodate of Potassa to Nitrate of Bismuth.

† If a small portion of muriatic acid be mixed with the nitric, and the precipitated oxide be washed with but a small quantity of cold water, it will appear in minute scales, constituting the *pearl powder of perfumers.* These paints are liable to be turned black by sulphuretted hydrogen.

‡ The compound analyzed by Vauquelin appears to have been a *bi-sulphuret.*—*Annales du Museum*, Tom. xv.

1312. *Native Sulphuret of Bismuth* has been found in Cornwall, Bohemia, Saxony and Sweden. It occurs massive and acicular, its lustre is metallic, and its colour bluish grey. It is a very rare mineral.

Sulphate

1313. *Sulphate of Bismuth.*—Sulphuric acid acts when hot and concentrated on bismuth, and sulphurous acid is disengaged. A part of the bismuth is dissolved; and the remainder is changed into an insoluble oxide. It consists of one proportional oxide and one acid. It is a white compound, insoluble in, but decomposed by water, which converts it into a *subsulphate* and *supersulphate.* The subsulphate described by Berzelius consists of three proportionals of oxide and 1 acid.

1314. *Hydrosulphuretted Oxide of Bismuth* is of a deep brown approaching to black. It is thrown down from nitrate of bismuth by sulphuretted hydrogen.

Alloys.

1315. Bismuth forms *alloys*, some of which are remarkable for their fusibility. With gold, platinum, and silver, it forms brittle compounds. A compound of eight parts of bismuth, five of lead, and three of tin, liquefies at 212°; it is called Sir I. Newton's *fusible metal.* The addition of one part of quicksilver renders it yet more fusible. Bismuth enters into the composition of *soft solders.* These alloys are mostly white, brittle, and easily oxydated.

Bismuth has the singular property of depriving gold of its ductility; even when combined with it in very minute proportion. This effect is produced by merely keeping gold in fusion near melted Bismuth. It has, nevertheless, been employed by Chaudet in cupellation. (*Ann. de Chim. et Phys.* viii. 113.) H. 2. 87.

SECTION XVII. *Cobalt.*

Ores.

1316. THE native combinations of cobalt are the oxide, and compounds of the metal with iron, nickel, arsenic, and sulphur. It is also found combined with arsenic acid. In the white and grey cobalt ores, the metal is combined with iron, and with arsenic: Some of the varieties are crystallized in cubes, octoëdrons and dodecaëdrons. The red ore is an arseniate. The finest specimens are the produce of Saxony.

To obtain pure cobalt.

1317. To obtain pure cobalt, the cobalt of commerce, in fine powder, may be calcined with four parts of nitre, and washed in hot water, by which arsenic is separated: then digest in dilute nitric acid, and immerse a plate of iron, which will separate the copper; filter and evaporate to dryness; digest the dry mass in liquid ammonia and filter, expel the excess of ammonia from the filtered liquor by heat, taking care not to produce a precipitate, and then add solution of potassa, which throws down oxide of nickel; filter immediately, and boil, which will occasion the separation of oxide of cobalt, and which, ignited with charcoal, furnishes the pure metal. In this process the first calcination with nitre often requires two or three repetitions in order to get rid of the whole of the arsenic, which adheres to cobalt with much obstinacy.

Properties.

1318. Cobalt has a greyish white colour, inclining to pink; its specific gravity is 8; it is brittle and easily reduced to powder, but is very difficultly fusible. When slowly cooled after fusion it may be obtained in irregular prisms. It is magnetic and was found by Wenzel to be convertible into a magnet, having all the properties of the magnetic needle.

Protoxide.

1319. By exposure to the atmosphere cobalt is tarnished, but not oxidized to any extent. In an intense heat it burns with a red flame; but, if pure, it is not easily oxidized by a moderate temperature. Its oxide, formed by long exposure to a strong heat with access of air, is of a deep blue, approaching to black. This, from the experiments of Thenard, appears to be the *protoxide*, which may be obtained, also, by precipitating the nitrate of cobalt with potassa. The precipitate, which at first is a bright blue hydrate, becomes when dry of so dark a blue as to appear black. It dissolves readily in muriatic acid, giving a solution which is green when concentrated, and red when diluted. Its solutions in sulphuric and nitric acids are always red. H. 2. 79.

1320. By exposure to heat and air the protoxide absorbs an additional portion of oxygen and is converted into black *peroxide*. All the salts of cobalt contain the protoxide.

Peroxide.

1321. The black or *peroxide*, heated for half an hour at the bottom of a crucible, loses a part of its oxygen, and is reduced to the state of protoxide. The protoxide is composed,

	Metal.	Oxygen.	Metal.	Oxygen.
According to Proust, of	83,5	16,5	100	19,8
———— Rothoff,	79,56	21,44	100	27,3
———— Thomson,			100	28,5
———— Brande,			100	24,7

And peroxide of cobalt consists,

	Metal.	Oxygen.	Metal.	Oxygen.
According to Proust, of	75	25	100	33,25
———— Rothoff,	71	29	100	40,85

Rothoff ascertained that 100 parts of peroxide of cobalt, exposed to a strong heat, lose from 9,5 to 9,9.* Taking the mean 9,7, we have 100 of the peroxide composed of 9,7 oxygen + 90,3 protoxide, the oxygen in which, according to the same authority, is 19,3. Therefore 9,7 + 19,3 = 29, is the oxygen in 100 of the peroxide; or 100 of the metal condense 40,85 oxygen. Hence the peroxide contains 1½ times as much oxygen as the protoxide. Assuming then the protoxide to consist of 1 atom metal + 1 atom of oxygen, the equivalent number for cobalt will be very nearly 30; for the protoxide 38; and for the peroxide 42. The anomaly of the fractional atom in the peroxide, may be got over by doubling the atom of cobalt, and considering the protoxide as 1 metal + 2 oxygen and the peroxide as 1 metal + 3 oxygen; but in that case the true protoxide, consisting of an atom of each element, must be supposed to be unknown. The subject indeed, appears to require further elucidation from experiment. H. 2. 80.

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* Ann. Phil. iii. 356.

Chloride.

1322. Cobalt burns when heated in chlorine; and forms *chloride of cobalt*. When muriate of cobalt is evaporated to dryness, and the residuum heated to redness out of the contact of air, a substance of a blue colour and micaceous texture is obtained, which is a pure chloride of cobalt. It dissolves perfectly in water, forming a pink solution.—Mr Brande from the analysis of the chloride infers that 100 of chlorine unite with 91,1 of cobalt; but this would give for the equivalent of that metal a higher number (32,54) than the number deducible from the composition of the oxide. H.

Muriate.

Sympathetic Ink.

1323. *Muriate of Cobalt* is a deliquescent salt, of a blue green colour; it may be formed by digesting either oxide in muriatic acid; if the peroxide be used, chlorine is evolved, and it passes to the state of protoxide. When a little diluted, this solution becomes pink; the pale pink solution, when written with, is scarcely visible; but if gently heated, the writing appears brilliant and green, which soon vanishes as the paper cools, in consequence of the salt absorbing the aërial moisture. This solution has been termed *Hellot's sympathetic ink.* It may be prepared as follows. One part of cobalt, or, still better, of zaffre, may be digested in a sand heat, for some hours, with four parts of nitric acid. To the solution, add one part of muriate of soda; and dilute with four parts of water. Characters written with this solution are illegible when cold; but when a gentle heat is applied, they assume a beautiful blue or green colour. This experiment is rendered more amusing by drawing the trunk and branches of a tree in the ordinary manner; and tracing the leaves with a solution of cobalt. The tree appears leafless, till the paper is heated, when it suddenly becomes covered with beautiful foliage. H. The addition of a little nitrate of copper to the solution forms a sympathetic ink, which by heat gives a rich greenish yellow colour. When a small quantity of muriate of soda, of magnesia, or of lime is added to the ink, its traces disappear very speedily on removal from the fire, showing that the vivid green, blue or yellow colour is owing to the concentration of the saline traces by heat, and their disappearance, to the re-absorption of moisture. U. 346.*

Nitrate.

1324. With nitric acid the oxide of cobalt furnishes a red deliquescent *nitrate of cobalt*. The crystals of nitrate of cobalt, are small prisms of a red colour. They are deliquescent in the air and decomposable by heat, leaving a deep red powder. When thrown into a flask full of liquid potassa, they are immediately decomposed. A blue precipitate is formed, which, if the flask be immediately closed, passes to violet, and afterwards to red, by becoming the *hydrate* or *hydrated oxide* of cobalt. This compound is soluble in cold carbonate of potassa and tinges it red. The oxide is not soluble in this liquid. The hydrate loses from 20 to 21 per cent. of water by heat, and is reduced to protoxide. Solutions of cobalt are precipitated by carbonated alkalies, at first of a peach-flower colour, and afterwards of a lilac hue. H. 2. 81.

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* *Iodide* and *Iodate of Cobalt* remain unexamined. No precipitate is produced in muriate of cobalt either by hydriodic acid or hydriodate of potassa.

Action of ammonia.

1325. Ammonia digested upon recently precipitated protoxide of cobalt slowly dissolves it, and forms a pale pink solution, which becomes deeper coloured by exposure to air, in consequence of the metal passing to the state of peroxide. The ammoniacal solution of the peroxide forms acicular crystals of a beautiful pink colour.[*]

Sulphate.

1326. *Sulphate of Cobalt.*—Sulphuric acid does not attack cobalt unless when concentrated and heated; nor does it readily dissolve the oxide. They may, however, be brought to combine by dissolving the newly precipitated protoxide in sulphuric acid diluted with its bulk of water. Small red prismatic crystals are obtained composed of one proportional of oxide, one of acid and seven of water.[†]

When dried at a temperature of 500°, the crystals fall into a blue powder, which in a bright heat fuses and gives out sulphuric acid leaving a black oxide. The blue powder is the *anhydrous sulphate of cobalt*, perfectly soluble in water, and forming a pink solution; it is slightly deliquescent, and becomes lilac coloured by exposure to air.

Anhydrous sulphate.

1327. Sulphate of cobalt forms triple compounds with potassa and with ammonia, which have not been examined. If it contain nickel, the crystals are of a greenish tinge, but pink when the cobalt is pure.[‡]

Phosphate.

1328. *Phosphate of Cobalt* may be formed by decomposing the nitrate of cobalt with phosphate of soda; it is insoluble, of a lilac colour, and if mixed with eight parts of gelatinous alumina and heated, it produces a beautiful blue, which may sometimes be employed by painters as a substitute for ultramarine. (For a full description of the process see THENARD, *Traité de Chim.* Ed. 4, vol. 3d, p. 146.) This salt was obtained by Dr Thomson by dissolving carbonate of cobalt in phosphoric acid and mixing the solution with alcohol. A copious precipitate falls, which was collected on a filter, edulcorated, first with alcohol and then with water. It was gelatinous and had a fine crimson colour. When dried, it concreted into a hard dark red matter, which

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[*] *Sulphuret of Cobalt* is formed by heating the oxide with sulphur. It is yellowish white.

[†]

Sulphuric acid	54,08	100
Protoxide of Cobalt	45,92	85
	100	Thomson.

[‡] *Hydrosulphuretted Oxide of Cobalt* is precipitated from the muriat by hydrosulphuret of ammonia, of a black colour. *Phosphuret of Cobalt* is a white brittle compound

reddened vegetable blues.* Dr Thomson considers it as composed of 1 atom phosphoric acid, 1 protoxide of cobalt and 2 of water.

Carbonate. 1329. *Carbonate of Cobalt* is formed by decomposing the nitrate, muriate, or sulphate of cobalt by carbonate of potassa, or soda; a reddish blue powder is precipitated which should be washed thoroughly with water. When dry, it is a light powder having a light pink colour. It is tasteless, insoluble in water, and not altered by exposure to the air. It does not alter vegetable blues, but dissolves in acids with effervescence. It consists of 1 atom carbonic acid, 1 protoxide of cobalt and 1 water. T.

1330. Ferrocyanate of potassa forms a grass green precipitate in solutions of cobalt.

Borate. 1331. Solution of borax produces a pink precipitate in solution of muriate of cobalt, which is probably a *borate of cobalt.*

1332. The salts of cobalt all contain the protoxide; they are decomposed by ammonia, which, if added in excess, re-dissolves the oxide: phosphoric, carbonic, arsenic, and oxalic acids, produce, by double decomposition, insoluble red or lilac precipitates in these solutions.

1333. The alloys of cobalt are unimportant.

Uses. 1334. The chief use of cobalt is as a colouring material for porcelain, earthenware, and glass; it is principally imported from Germany in the state of *zaffre*, and *smalt*, or *azure*.

The colouring power of oxide of cobalt on vitrifiable mixtures, is greater perhaps, than that of any other metal. One grain gives a full blue to 240 grains of glass. U.

Zaffre. *Zaffre* is prepared by calcining the ores of cobalt, by which sulphur and arsenic are volatilized, and an impure oxide of cobalt remains, which is mixed with about twice its weight of finely powdered flints.

Smalt. *Smalt* and *azure blue* are made by fusing zaffre with glass; or by calcining a mixture of equal parts of roasted cobalt ore, common potash, and ground flints. In this way a blue glass is formed, which, while hot, is dropped into water, and afterwards reduced to a very fine powder.

SECTION XVIII. *Uranium.*

Discovery. 1335. THIS metal was discovered by Klaproth, in 1789, in a mineral called *pitchblende*, which contains uranium combined with sulphur, and according to Arfwedson, arsenic, cobalt, and zinc.† From this ore uranium may be obtained by the following process: reduce it to powder, and expose it to heat in a muffle; then digest in dilute nitro-muriatic acid, and precipitate by excess of ammonia, to retain oxide of copper; collect and wash the precipitate, and dry it at a heat approaching redness.

Process for obtaining the metal.

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* T. First Principles, ii. 344.

† Mem. Acad. Sci. of Stockholm, 1822.

When exposed to a violent heat with a small quantity of ırcoal powder, metallic uranium is obtained.

Arfwedson's.

M. Arfwedson has succeeded in reducing the protoxide of ınium to a metallic state, by passing a current of dry hydron gas over it while hot. The metal thus obtained was in rstals having nearly the form of regular octoëdrons, with a ong metallic lustre, and a reddish brown colour.

Its specific gravity has not been ascertained with precision. ıcholz states it as = 9,0.—GEHLEN's *Journal*, iv.

1336. Uranium may be exposed to the air in ordinary temratures without alteration, but when heated it undergoes a nd of combustion, and is converted into a black oxide.

Oxides.

1337. There appear to be two oxides of uranium, the *yellow* e, which retains its colour when heated alone, and becomes the *ıck* oxide, when heated with a little oil. The first, or perox-e, according to Bucholz, consists of 80 metal + 20 oxygen, t the composition of the black oxide is not yet determined. cording to the experiments of Schoübert,* the composiın of the protoxide of uranium, deduced from the analysis of e muriate, is 100 metal + 6, 373 oxygen; and the multiple the oxygen in the peroxide, being, according to the same thority 1½, we have 100 metal + 9,569 oxygen for the comsition of the peroxide. This would make the weight of the om of uranium 125, of the protoxide 133, and of the peroxide 7. But from a series of experiments which are described in e Jour. of the Roy. Institut. xix. 88, it seems probable that may be the equivalent number. The subject, however, still mains in considerable uncertainty. H. 2. 75.

Protoxide.

1338. *Protoxide of Uranium*, obtained by exposing the perrbonate of uranium and ammonia to a red heat, is composed small grains, having a black colour, and a good deal of lustre; t when reduced to powder, it has a dark green colour. It is luble in muriatic and sulphuric acid; but the solution goes on ıwly, except when the oxide is in the state of hydrate. The lutions are green, and the protoxide is thrown down in the ıte of a brown coloured hydrate, which dissolves easily in ids, forming a dark green solution. It dissolves readily in tric acid, with the evolution of nitrous gas, and is converted to peroxide.

The protoxide of uranium is tasteless, and not altered by exsure to the air. It combines readily with the acids; all its lts have a green colour and are uncrystallizable.

Peroxide.

1339. *Peroxide of Uranium* affords salts, having for the ost part a lemon yellow colour. Its tendency to combine with her bodies is such, that it seems impossible to obtain it in a parate state. It dissolves with ease in nitric acid, and forms lemon yellow solution of great intensity, which crystallizes d forms the nitrate of uranium in fine lemon yellow crystals, having the form of right four-sided prisms with square bases. The addition of carbonate of ammonia affords a yellow powder, which is most frequently a percarbonate of uranium, but sometimes, a triple salt composed of carbonate of ammonia and percarbonate of uranium. Potash and soda afford a beautiful orange red powder, which is a triple compound of percarbonate of uranium and an alkaline carbonate.

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* Thomson's Chem. i. 427.

1340. Arfwedson has shown, that if we mix together solution of pernitrate of uranium and any earthy or metallic nitrate, and add caustic ammonia or potash to the solution, the peroxide of uranium precipitates in chemical combination with the earthy or metallic oxide present. Thus it appears, that peroxide of uranium is capable of uniting both with acids and with bases; so that it performs the double function of an alkali and an acid.*

Precipitated by ammonia.

1341. The hydrated oxide precipitated by ammonia from nitric acid, when gently dried consists of 88 oxide, and 12 water in 100. It is precipitated again by alkalies, and is thrown down, of a reddish brown colour by prussiates. Sulphuret of ammonia gives a brownish yellow precipitate; and tincture of galls, a chocolate brown one. When exposed to intense galvanic action, it is fused, but not reduced.

The yellow oxide of uranium is insoluble in alkalies, which distinguishes it from the oxide of tungsten. It is soluble, however, by alkaline carbonates, especially by carbonate of ammonia. H. 2 74.

Nitrate.

1342. This metal is most soluble in nitric acid. The *Nitrate* forms prismatic brownish yellow crystals which have a peculiar irridescent appearance, are deliquescent, and are constituted according to Bucholz† of 61 base, + 25 acid + 14 water.

1343. *Subnitrate of Uranium*, upon the authority of Bucholz, is formed by heating the nitrate, which renders a part insoluble in water, and separates in the form of a yellow powder.

1344. Uranium according to Berzelius has a very weak affinity for sulphur. *Sulphuret of Uranium* exists native. Neither the *Hyposulphite* nor *Sulphite of Uranium* have been examined.

1345. *Sulphate of Uranium* forms yellow prismatic crystals, decomposable by heat, and according to the analysis of Bucholz, consisting of 70 oxide, 18 acid and 12 water.

Characteristics of salts of uranium.

1346. The salts of uranium have a yellow colour and an astringent metallic taste. Potassa forms in their solutions a yellow precipitate, and carbonate of potassa a white precipitate; both these precipitates are insoluble in excess of pure alkali, but dissolve in the carbonate.‡ Ferrocyanate of potassa produces a rich brown precipitate in solutions of uranium, which is very characteristic.

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* Thomson's *First Prin.* 2. 7.

† Gehlen's *Jour.* iv.

‡ Dr Thomson found that the precipitate obtained by caustic soda, from the solution of the pernitrate, was re-dissolved by an excess of the alkali. *First Princip.* ii. 8.

SECTION XIX. *Titanium.*

Discovery of metallic titanium.

1347. Titanium in the metallic state, was discovered by Dr Wollaston, in 1822, in the slag at the bottom of the iron smelting-furnace at Merthyr Tydvil in South Wales.* It has been since found in several other places in Europe. It has the form of small smooth cubes, having a red colour, exceedingly similar to that of copper. The cubes are hard enough to scratch rock crystal, and cannot be fused by the highest temperature which can be raised by the blow-pipe. The specific gravity as determined by Dr Wollaston, is 5,3.† From the situation in which this metallic titanium has been found, we may infer that it does not combine with iron, and Dr Wollaston tried in vain to unite it with lead, tin, silver and copper. It does not appear, however, to be absolutely free from iron; Dr Wollaston found that when suspended by a fine thread a magnet drew it about 20 degrees from the perpendicular. He succeeded in detecting the presence of iron in it, and calculated the amount of that metal at $\frac{1}{15}$th part of the weight of the titanium.‡

Oxides.

1348. Titanium is said to be susceptible of three degrees of oxidizement, the colours of the oxides being blue, red, and white.

The *blue* is formed by exposing the metal to heat and air; the *red* is the native oxide; and the *white* is that which is precipitated from the alkaline solution of titanite and menachanite by muriatic acid. B.

1349. Titanium exists in the state of oxide in two minerals, in titanite and menachanite.

Titanite.

Titanite is of a brown colour, and occurs embedded in the quartz and granite of primitive countries, and sometimes traverses rock crystals in fine hair-like filaments.

The mineral, known by the name of *anatase*, *octoëdrite*, and *oysanite*, is nearly of the same nature as titanite.§

Process for obtaining the metal.

1350. The metal may be obtained from titanite by fusion with potassa; the fused mass, washed with water, leaves oxide of titanium, containing a little iron; it is to be dissolved in muriatic acid, and precipitated by oxalic acid. B.

1351. From the mineral called menachanite, white oxide of titanium may be obtained by fusing with potassa, and adding muriatic acid to the alkaline solution.

Reduction of the oxide.

1352. The oxide of titanium fuses, but is not reduced by a powerful galvanic battery. It is reduced, however, by exposure to an intense heat, moistened with oil, and surrounded by powblood. A rod of tin, immersed in the solution, imparts to the liquid around it a fine red colour; and a rod of zinc, a deep blue one.

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* Philos. Trans. 1823.

† From the extreme infusibility of the cubes of metallic titanium, Dr Wollaston infers that they have not been formed by crystallization in cooling from a state of fusion; but from the reduction of the oxide dissolved in the slag around them.

‡ Phil. Trans. p. 200. Thomson's *First Princip.* 2. 80.

§ For other ores of this metal see Cleaveland's Mineralogy, 700.

Section XX. *Cerium.*

1361. This metal was obtained by Hisinger and Berzelius, from a mineral found at Bastnas in Sweden, to which they have given the name of *Cerite.*[*] It is also contained in *Allanite*, a mineral from Greenland, first distinguished as a peculiar species by Mr Thomas Allan, of Edinburgh. It contains, according to Dr Thomson's analysis, about 40 per cent. of oxide of cerium.

How obtained.

The ore is calcined, pulverized, and digested in nitro-muriatic acid. To the filtered solution saturated with potassa, oxalic acid is added, which occasions a precipitate; this, when dried and ignited, is oxide of cerium.

This oxide is extremely difficult of reduction. Mr Children succeeded in fusing it by the aid of his powerful Voltaic apparatus, and when intensely heated it burned with a vivid flame, and was partly volatilized.

Vauquelin's experiments.

1362. The attempts of Vauquelin to reduce the oxide of cerium produced only a small metallic globule, not larger than a pin's head. This globule was not acted upon by any of the simple acids; but it was dissolved, though slowly, by nitro-muriatic acid. The solution was reddish, and gave traces of iron; but it also gave evident marks of cerium, by the white precipitate which tartrite of potassa and oxalate of ammonia threw down. The metallic globule, also, was harder, whiter, much more brittle, and more scaly in its fracture, than pure cast-iron. The oxide fused, by Mr Children's battery, (1361) on exposure for a few hours to the air, fell into a light brown powder, containing numerous particles of a silvery lustre. Hence cerium appears to be a volatile metal, unless it be volatilized in the state of an oxide, which remains to be decided by future experiments. H. ii. 78.

Oxides.

1363. Vauquelin[†] and Hisinger have described two *oxides of cerium.* The *protoxide* is white, and consists of cerium 100 + oxygen 17,41. The *peroxide* is brown, and contains cerium 100 + oxygen 26,11. If we regard the first oxide as constituted of 2 atoms of oxygen + 1 of metal, the equivalent for cerium will be 92; if of one atom only of oxygen + 1 atom of metal, the representative number of cerium will be 46; that of the protoxide 54; and that of the peroxide 62. H.

1364. Muriatic and sulphuric acids dissolve the red peroxide of cerium, and the solutions afford yellow crystals. The muriate is deliquescent; the sulphate difficultly soluble. The sulphate of the protoxide forms white crystals of a sweet taste. Nitric acid forms with the protoxide a deliquescent compound, of a sweet taste. The carbonate is precipitated from these solutions in the form of a white powder.

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[*] The name *Cerium* was given to this metal from the planet *Ceres*, discovered about the same period. See Nicholson's Jour. xii. 105.

[†] Annales de Chimie, iv.

1365. The salts of cerium are either white or yellow, as they contain either the protoxide or peroxide. Their neutral solutions taste sweet. Ferrocyanate of potassa, and oxalate of ammonia, produce white precipitates soluble in nitric and muriatic acids. Neither sulphuretted hydrogen, nor gallic acid, occasion any precipitate. B. Salts of cerium.

An infusion of galls produces, in muriate of cerium a yellowish precipitate not very abundant. A few drops of ammonia thrown down a very voluminous one of a brown colour, which becomes black and brilliant, by desiccation. By the action of heat, it assumes a brick-red colour. H. ii. 77.

SECTION XXI. *Tellurium.*

1366. THE ores of tellurium are, 1. *Native*, in which the metal is combined with iron and a little gold. 2. *Graphic ore*, a compound of tellurium, gold, and silver. 3. *Yellow ore*, a compound of tellurium, gold, lead, and silver; and 4. *Black ore*, consisting of the same metals with copper and sulphur. Ores.

These ores have been found in the Transylvania mines, in Siberia, and at Huntington in the state of Connecticut.*

Tellurium was discovered by Klaproth,† in an ore of gold. His process for extracting it consists in the solution of the ore by nitro-muriatic acid, dilution with water, and the addition of pure potassa, which throws down all the metals that are present; and, when added in excess, re-dissolves a white precipitate which it at first occasions. To the alkaline solution, muriatic acid is then added; a precipitate again appears; and this, when dried and heated with one twelfth its weight of charcoal, or with a small quantity of oil, in a glass retort, yields tellurium, in the form of small brilliant metallic drops, lining the upper part of the body of the retort.—One hundred parts of the ore yield above 90 of tellurium. H. 2. 100. Process for obtaining tellurium.

1367. Tellurium is of a bright grey colour, brittle, easily fusible, and very volatile. Its specific gravity is 6,1. Properties.

1368. It is oxidized when heated in contact with air; and burns with a sky-blue flame, edged with green. Upon charcoal, before the blow-pipe, it inflames with a violence resembling detonation; exhibits a vivid flame; and entirely flies off in a grey smoke, having a peculiarly nauseous smell. This smoke, when condensed, and examined in quantity, is found to be white with a tint of yellow. It is fusible by a strong heat, and Oxide.

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* Amer. Jour. of Science, i. 405.

† Contributions, ii. 1.

volatile at a still higher temperature. It not only unites as a base with acids, but also itself possesses the character of an acid, and forms a class of salts, which may be called *tellurates.* It is composed, according to Klaproth of

Tellurium	83	100,
Oxygen	17	20,5
	100	

Weight of its atom.

Berzelius, however, determines the quantity of oxygen, absorbed by 100 of tellurium, when changed into oxide, to be 27,83. If this result be correct, and the compound be the protoxide, the atom of tellurium should weigh 29; but the determination of Klaproth would make it 39. H. 2. 101.

Action of nitric acid,

1369. Tellurium is soluble in nitric and nitro-muriatic acids. The saturated solution is decomposed by the mere addition of water, which throws down a white powder; but this is again dissolved on adding more water. Chlorine unites with tellurium, and forms a white semi-transparent compound, which is decomposed when added to water. It consists, according to Sir H. Davy, of 100 tellurium united with 90,5 chlorine. From its solutions it is precipitated in a metallic form, by iron, zinc, tin, and even by muriate of tin. Carbonated and pure alkalies precipitate the telluric oxide united with water, in the form of a white hydrate; and the oxide is re-dissolved by an excess of alkali or carbonate. Alkaline sulphurets throw down a dark brown or blackish precipitate. Tincture of galls produces a flocculent yellow precipitate. The solutions of this metal in acids are not decomposed by prussiate of potassa; a property which tellurium possesses in common with gold, platinum, iridium, rhodium, and antimony.

—of chlorine.

— of sulphuric acid.

1370. It gives a deep purple colour to sulphuric acid, from which it is thrown down in black flocculi by water; but if the acid be diluted with two or three parts of water to which a little nitric acid has been added, a large portion of the metal is dissolved, and the solution is not decomposed by water. U. 742.

Union with hydrogen.

1371. Tellurium forms two distinct compounds with hydrogen, the one of which is solid, and the other gaseous. 1st. By making tellurium the negative surface in water, in the galvanic circuit, a brown powder is formed, which is a solid *hydruret of tellurium.* 2dly. By acting with dilute sulphuric acid, upon the alloy of tellurium and potassium (which may be obtained by heating a mixture of solid hydrate of potassa, tellurium, and charcoal), we obtain a peculiar gas. This gas has a smell resembling that of sulphuretted hydrogen. It is absorbed by water, and a claret-coloured solution results, which, by exposure to the air, becomes brown, and deposits tellurium. After being washed with a small quantity of water, it does not affect vegetable blue colours. It burns with a bluish flame, depositing oxide of tellurium. It unites with alkalies; precipitates most metallic solutions; and is instantly decomposed by chlorine gas. It may be called *telluretted hydrogen gas*. According to Berzelius, it is constituted of 100 parts of tellurium with a little less than two parts of hydrogen. H. 11. 102.

1372. According to Dr Thomson, the specific gravity of telluretted hydrogen is 2,916, and 100 cubical inches weigh 69,895 grains.

Tellurate of potassa.

1373. *Tellurate of Potassa* may be formed by heating oxide of tellurium with nitre, and dissolving the residuum in boiling water, which, on cooling, deposits an imperfectly crystallized white powder, difficultly soluble in water.

1374. Solution of tellurate of potassa, added to solutions of lime, baryta, strontia, copper, and lead, forms insoluble tellurates of the oxides of those metals.

SECTION XXII. *Selenium.*

1375. This body is placed, rather from analogy than experiment, among the metals.

Sources of selenium.

In the chambers for manufacturing sulphuric acid, from the sulphur which is procured at Fahlun in Sweden, a reddish mass is deposited, which is principally sulphur.* This substance, in burning, gave out an odour, which induced Berzelius to suspect that it contained tellurium, but on a minute examination he discovered, instead of that metal, a body with entirely new properties, to which he has given the name of *Selenium*. The process by which it was extracted, is described in the 13th vol. of Annals of Philosophy, p. 403; but as the source of it is extremely rare, it will be sufficient to refer to Berzelius' description.

Properties.

1376. The colour of Selenium varies a good deal. When rapidly cooled, its surface has a dark brown hue, and its fracture the colour of lead. Its powder has a deep red colour, but it sticks together when pounded, and then assumes a grey colour and a smooth surface. It softens at 212° Fahr., and completely fuses at a few degrees higher. While cooling, it has a considerable degree of ductility, and may be kneaded between the fingers, and drawn out into fine threads, which have a strong metallic lustre, an imperfect degree of transparency; and are red by transmitted, but grey by reflected light. When slowly cooled it assumes a granulated fracture, and is extremely like a piece of cobalt. At a temperature nearly equal to that of boiling mercury, selenium enters into ebullition; and condenses, either into opaque metallic drops, or, when a retort with a large neck is used, into flowers of a fine cinnabar colour. Its vapour has a deep yellow colour, more intense than that of chlorine, but not so deep as that of sulphur.

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* It has been lately discovered by M Stromeyer amongst the volcanic products of the Lipari islands, and the peculiar orange tint of the sulphur from those islands is supposed to proceed from its presence. *See Ann. Philos. N. S.* x. 234.—Professors Stromeyer and Hausmann have given an account of a new ore of lead containing selenium. See Bost. Jour. ii. 597.

1377. When heated before the blow-pipe, it tinges the flame of a fine azure blue, and exhales so strong a smell of horse-radish, that a fragment, not exceeding $\frac{1}{50}$ of a grain, is sufficient to fill the air of a large apartment.

Oxide.

1378. *Selenium and Oxygen.*—Oxide of Selenium is formed by heating Selenium in a close phial with common air, which acquires a strong smell of horse-raddish. Water agitated with this air imbibes the odour of the gas, and reddens litmus feebly, but this appears to be owing to the production of a small quantity of selenic acid. Selenic oxide gas is very sparingly soluble in water, and does not impart any taste to it. It does not combine with liquid alkalies.

Selenic acid.

1379. *Selenic acid.*—Selenium dissolves in nitric and nitro-muriatic acids, and when the solution is evaporated in a retort, so as to expel the excess of those acids, there remains a white saline mass, which sublimes on raising the temperature, and forms a vapour, the colour of which closely resembles that of chlorine. In the cold part of the apparatus, selenic acid condenses in very long four-sided needles. These crystals, when first taken out of the retort, have a dry aspect, and a peculiar lustre. Exposed to the air, they adhere to each other, and the lustre becomes dull, but they do not liquefy.

Properties.

1380. Selenic acid has a sour taste, and leaves a slightly burning sensation on the tongue. It is very soluble in cold water, and dissolves in almost every proportion in boiling water. A saturated solution crystallizes, when rapidly cooled, in small grains, and when slowly cooled in striated prisms. The crystals dissolve in great abundance in alcohol, and the solution, when distilled, yields a fluid having an ethereal smell.

Selenic acid unites with different bases, and forms a class of salts called *Selenates* or *Seleniates.*

Selenic acid is easily reduced both in the moist and the dry way. When a plate of zinc or polished iron is introduced into a solution of selenic acid mixed with muriatic acid, selenium is precipitated in the form of red, or brown, or blackish plates. It is revived, also, by sulphuretted hydrogen, and sulphurous acid gases.

1381. From his investigation of selenic acid, Berzelius has inferred it to consist of

Composition.

Selenium	71,261	100,00
Oxygen	28,739	40,33
	100.	

On the supposition that it is constituted of an atom of base + 2 atoms of oxygen, the equivalent number for selenium will be 41, and for seleniç acid 57.

Union with chlorine.

1382. *Selenium and Chlorine.*—Selenium absorbs chlorine gas, and becomes hot and forms a brown liquid, which, by an additional quantity of chlorine, is converted into a white solid mass. This is stated by Berzelius to be a compound of muriatic and selenic acids, but it is probably composed of chloride of selenium and the latter acid. It has not yet been accurately separated into its component parts, for when heat is applied, both substances are sublimed. H. 1. 391.

1383. Selenium unites with the metals. With potassium it combines with great energy, producing a greyish compound, with metallic lustre, and which, when thrown into water, evolves *selenuretted hydrogen gas,* which is highly irritating to the nostrils. B.

Analogous to sulphur.

1384. While this body possesses some of the characters of metals, (the metallic lustre for example,) it is destitute of others that are essential to its arrangement in that class. It has more transparency than any metal, and is distinguished, also, from the metals, by the want of power to conduct electricity or heat. In some respects it resembles tellurium; but, on the whole, its properties are most analogous to those of sulphur; and it may be regarded as forming the connecting link between metals and non-metallic combustibles. H. 394.

SECTION XXIII. *Arsenic.*

To obtain metallic arsenic.

1385. ARSENIC, as it is found under that name in the shops, is not a metal, but a white oxide, from which the metal may be obtained by mixing it with half its weight of black flux,[*] and introducing the mixture into a Florence flask, placed in a sand bath, gradually raised to a red heat: a brilliant metallic sublimate of pure arsenic collects in the upper part of the flask. The volatility of white arsenic prevents its easy reduction by charcoal alone; but the potassa in the flux enables it to acquire a temperature sufficient for its perfect reduction.

Characters.

1386. Arsenic is of a steel blue colour, quite brittle, and of a specific gravity = 8,3. It readily fuses, and in close vessels may be distilled at a temperature of 360°, which is lower than its fusing point. Its vapour has a very strong smell, resembling that of garlic. Heated in the air it easily takes fire, burns with a blue flame, and produces copious white fumes of oxide. Exposed to a moist air it gradually becomes incrusted with a grey powder, which is an imperfect oxide. This metal and all its compounds are virulent poisons.

Native.

1387. *Native arsenic* usually occurs in rounded masses, or nodules, of a foliated lamellar texture, in the veins of primitive

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Black flux.

[*] This is an extremely useful compound for effecting the reduction of many of the metallic oxides. It consists of charcoal and subcarbonate of potassa, and is best prepared by deflagrating in a crucible a mixture of one part of nitre and two of powdered tartar. The mixture remains in fusion at a red heat, and thus suffers the small globules of reduced metal to coalesce into a button.

rocks, and is often associated with silver, cobalt, lead, and nickel ores.

Arsenic and oxygen.

1388. *Arsenic and Oxygen.*—There are two definite compounds of arsenic and oxygen, which are both capable of forming combinations with other metallic oxides. They are sour and soluble in water, and have thence been properly termed *arsenious* and *arsenic acids.*

Arsenious acid.

The arsenious acid, or, as it is commonly called, *white arsenic,* or *white oxide of arsenic,* is the best known, and most commonly occurring compound of this metal; and as cases of poisoning by it are frequent, every person should be well acquainted with its characteristic properties.

How obtained.

1389. Arsenious acid may easily be procured by the combustion of the metal; but as it is formed during certain metallurgic processes, that mode is rarely resorted to. It is abundantly prepared at Joachimsthal in Bohemia, from arsenical cobalt ores, which are roasted in reverberatory furnaces, and the vapours condensed in a long chimney, the contents of which, submitted to a second sublimation, afford the *white arsenic* of commerce.

Properties.

1390. Arsenious acid is white, semi-transparent, brittle, and of a vitreous fracture. Its specific gravity is 3,7. Its taste is acrid, accompanied by a very nauseous sweetness, and it is virulently poisonous, producing inflammation and gangrene of the stomach and intestines; it also proves fatal when applied to a wound; and as the local injury is in neither case sufficient to cause death, it is probable that an induced affection of the nervous system and of the heart is the cause of the mischief.[*] To get rid of the poison by producing copious vomiting and purging, and to pursue the usual means of subduing and preventing inflammation, are the principal points of treatment to be adopted in cases where this poison has been taken.[†]

Action of water.

1391. By a slow sublimation arsenious acid forms tetraëdral crystals; it is volatile at 380°, and has no smell when perfectly free from metallic arsenic.[‡] According to Klaproth, 1000 parts of water at 60° dissolve 2,5 of white arsenic; and 1000 parts of water at 212°, dissolve rather more than 77 parts, and about 30 parts are retained in permanent solution.—But the most elaborate experiments are those of Fischer of Breslau. According to these, white oxide of arsenic is insoluble as such in water, and, when acted upon by water, one portion of the oxide acquires oxygen from another, and, becoming acidified, is rendered soluble. This is the reason why the undissolved portion loses its colour, and becomes of a dirty yellow. Of boiling water, 12,3 parts dissolve one of arsenic; but at the common temperature of the atmosphere, 66½ parts of water take up only one part.[§] H.

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[*] Brodie's *Observations and Experiments on the Action of Poisons.* Phil. Trans. 1812.

[†] Orfila, *Traite des Poisons,* Tom. i. p. 123.

[‡] Dr Paris, *Quarterly Journal of Science and Arts,* Vol. vi.

[§] Thomson's *Annals,* vii. 33.

The solutions taste acrid and nauseous, and redden vegetable blues. 80 parts of alcohol at 60°, dissolve one part of this acid. Its aqueous solution furnishes tetraëdral crystals by slow evaporation.

Equivalent number. 1392. From late experiments Dr Thomson has deduced the weight of the atom of arsenic to be 4,75 oxygen being 1; this corresponds with 38 when hydrogen is taken as unity; and he considers arsenious acid as composed of 1 atom arsenic and 2 atoms oxygen; and arsenic acid of 1 arsenic + 3 oxygen, giving 6,75 for the representative number of arsenious acid on the oxygen scale, or 54 on the hydrogen; and arsenic acid will be represented on the former by 7,75, on the latter by 62.*

1393. *Native White Arsenic* occurs in prismatic crystals, and in a pulverulent form; it is found in Saxony and Hungary.

1394. The arsenious acid forms a distinct class of salts, called *arsenites*, which have been but little examined.

Arsenites. The *arsenites of ammonia, potassa,* and *soda*, are easily soluble and uncrystallizable: they are formed by boiling the acid in the alkaline solutions. Those of *lime, baryta, strontia,* and *magnesia*, are difficultly soluble, and formed in the same way. Arsenite of potassa is the active ingredient in the *liquor potassæ arsenitis* of the *U. S. Pharmacopœia,* and in *Fowler's mineral solution* or *tasteless ague drop.*

Arsenite of ammonia produces a yellow precipitate in nitrate of silver, easily soluble in excess of ammonia.

— of potassa. 1395. Arsenite of potassa produces a white precipitate in the white salts of manganese; a dingy green precipitate in the solutions of iron; a white precipitate in solutions of zinc and tin. Mixed with a solution of sulphate of copper, a precipitate of a fine apple green colour falls, called from its discoverer, *Scheele's green*, and is useful as a pigment. In the solutions of lead, antimony, and bismuth, it forms white precipitates: added to nitrate of cobalt it forms a pink precipitate; and bright yellow, with nitrate of uranium. With nitrate of silver it forms a white precipitate, soon becoming yellow, and very soluble in ammonia. All these precipitates are probably *arsenites* of the respective metals, and, heated by a blow-pipe on charcoal, they exhale the smell of arsenic.

Arsenic acid. 1396. By repeated distillation with nitric acid only, arsenious acid is changed into *arsenic acid.* Or a mixture of 4 parts of muriatic and 24 of nitric acid may be distilled off 8 parts of arsenious acid, gradually raising the bottom of the retort to a red heat at the end of the operation. It may also be procured by distilling nitric acid off powdered metallic arsenic.

Properties. 1397. Arsenic acid is a white substance, of a sour taste; it is deliquescent and uncrystallizable. Its specific gravity is 3,4. It requires for solution 6 parts of cold and 2 of boiling water; its solution reddens vegetable blues, and tastes acrid and metallic.

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* See *First Princip.* 2.

Ratio of the oxygen in arsenic and arsenious acids.

1398. It appears from the experiments of Proust and Thomson, that the oxygen in the arsenic acid is, to that in the arsenious acid, as 3 to 2; hence we may regard it as a compound of 1 proportional of arsenic = 38, and 3 proportionals of oxygen = 24, and its representative number will be 62.—Berzelius, has been led, by his investigation of these acids, to conclude that the ratio of the oxygen in arsenic acid is to that in arsenious acid as 5 to 3, a deviation from the general law of acid compounds, limited to those with base of arsenic and phosphorus. Between these acids, indeed, there seems to be, in several respects, a considerable analogy, especially in their salts, which, though carefully neutralized when in solution, yet when concentrated by evaporation, crystallize with an excess of alkali. H. 2. 50.

Arseniates.

1399. The *Arseniates* are produced by the union of this acid with the metallic oxides; and many which are insoluble may be formed by adding arseniate of potassa to their respective solutions.

— of ammonia.

1400. *Arseniate of Ammonia* is formed by saturating arsenic acid with ammonia; rhomboidal prisms are obtained on evaporation, which, when gently heated effloresce and evolve ammonia; at a higher temperature pure water is formed, oxide of arsenic sublimes, and nitrogen is evolved, a circumstance first observed by Scheele.

— of potassa.

1401. *Binarseniate of Potassa* may either be formed by adding excess of arsenic acid to potassa and evaporation; or by heating to redness, in a Florence flask, a mixture of equal parts of nitre and white arsenic; during the latter operation much nitrous gas is evolved, and on dissolving the residue in water, filtering, and evaporating, quadrangular crystals of binarseniate of potassa are obtained. Macquer was the first who procured this compound, hence it was termed *Macquer's neutral arsenical salt.* It is not easily decomposed by heat alone, and may be fused and kept red hot without undergoing other change than losing a little acid, but when mixed with about an eighth of charcoal powder and distilled, metallic arsenic rises, and carbonate of potassa, mixed with a part of the charcoal, remains in the body of the retort. This salt is used in pharmacy for the cure of agues: it consists of

1 proportional of potassa . . . . =	48
2 ———— arsenic acid . . . . =	124
	172 B.

Dr Thomson's analysis makes it to consist of

Arsenic acid	65,426
Potassa	27,074
Water	7,500
	100.

— of soda,

1402. *Arseniate of Soda* is formed by saturating a solution of carbonate of soda with arsenic acid; on evaporation, crystals are obtained, which appear to consist of

1 proportional of soda . . . . = 32
1 ———————— arsenic acid . . . . . = 62

94

It has a cooling taste, resembling that of carbonate of soda, but less strong. It requires more than ten times its weight of cold water for solution, and the liquid has alkaline properties. It undergoes the watery fusion. Its solution, when dropped into most earthy and metallic salts, occasions precipitates, the peculiar appearances of which are exhibited by Dr Thomson in a table published in the Annals of Philosophy, xv. 83. H.

— of lime,

1403. *Arseniate of Lime* is deposited when arsenic acid is dropped into lime-water or when arseniate of potassa is added to nitrate of lime; it is difficultly soluble in water, and consists, according to Laugier[*] of arsenic acid 67, lime 33; numbers which do not exactly correspond with 1 proportional of acid + 1 of base.

— of Baryta,

1404. *Arseniate of Baryta* may be formed by mixing neutral-arseniate of soda with nitrate of baryta; when the acid is not in excess it is insoluble in water. It consists of

Arsenic acid	42,94	100,
Baryta	56,06	132,88
	100.	H.[†]

— of zinc,

1405. *Arseniate of Zinc* is precipitated in the form of a white insoluble powder when arsenic acid, or an alkaline arseniate, is added to sulphate of zinc.

— of tin,

1406. *Arseniate of Tin* is a white insoluble powder, precipitated by adding arseniate of potassa to muriate of tin.

— of copper,

1407. *Arseniate of Copper* is formed by adding an alkaline arseniate to nitrate of copper; it is a blue insoluble powder. The arseniates of copper have been submitted to an elaborate investigation by Mr Chenevix, he has described five varieties.[‡]

— of lead,

1408. *Arseniate of Lead.* It may be formed by pouring arsenic acid into any of the soluble salts of lead when it falls in the form of a white powder, insoluble in water, but soluble in dilute nitric acid; a circumstance which enables us in analysis to separate it from sulphate of lead, which is insoluble. This compound is fusible without decomposition; but if it be heated with charcoal, both the lead and arsenic are reduced, and the latter evaporates.

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[*] Annals de Chim. 85, 58.

[†] *Arseniate of Magnesia* is soluble, deliquescent, and uncrystallizable. *Arseniate of Manganese* is precipitated in the form of a white powder, by adding arseniate of potassa to muriate of manganese. *Arseniate of Iron*—Arseniate of ammonia, added to the solutions of protosulphate and persulphate of iron, occasions greenish precipitates of *protarseniate* and *perarseniate* of iron, both of which have been examined by Mr Chenevix. *Phil. Trans.* 1801, pp. 220, 225.

[‡] See Phil. Trans. 1801 —Thomson's *System*, ii. 463, Amer. edit.—and *First Principles*, ii. 281.

Native.

Arseniate of lead occurs *native*; the finest crystallized varieties are associated with silver at Johanngeorgenstadt in Saxony.* The arseniate from Cornwall, Eng. is inferred by Dr Thomson, from the analysis of Mr Gregor, to consist of 1 atom acid and 1½ protoxide of lead; that from Saxony of one atom of each of its constituents. T. 2. 371.†

Chloride.

1409. *Arsenic and Chlorine.—Chloride of arsenic* is formed by throwing finely-powdered arsenic into chlorine; the metal burns and forms a whitish deliquescent and volatile compound; it may also be obtained by distilling 6 parts of corrosive sublimate with 1 of powdered arsenic; the chloride passes into the receiver in the form of an unctuous fluid, formerly called *butter of arsenic*. Mixed with water, the chloride of arsenic is decomposed, and white oxide, or arsenious acid, is deposited, muriatic acid being at the same time produced. Hence it may be inferred, that the chlorine is to the arsenic in the same proportion as the oxygen, and, consequently, that it consists of 1 proportional of arsenic + 2 proportionals of chlorine, which, from Dr Davy's experiments, appears to be the case. B.

Dr Davy determined the composition of this compound‡ by synthesis, and states it to consist of

Dr Davy's analysis.

Chlorine	60,48	100
Arsenic	39,52	65,3
	100.	

This analysis, however, does not lead to an atomic weight for arsenic at all coinciding with that deduced from the oxides. From the name which Dr Davy gives to this compound, it is evident that he considers it as the protochloride; but in that case the atom of arsenic would weigh only 23,4.; for 100 : 65 : : 36 : 23,4. There is, probably therefore, some error in the estimate of its composition. H. 2. 51.

Chlorate.

Exp.

1410. *Chlorate of Arsenic* has not been examined, but chlorate of potassa and metallic arsenic afford a detonating mixture, which takes fire with amazing rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with a knife point. If two long trains be laid on a table, the one of gunpowder, and the other of this mixture, and they be placed in contact with each other at one end, so that they may be fired at once, the arsenical mixture detonates with the rapidity of lightning, while the other burns with comparatively extreme slowness. H.

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* Moh's Mineralogy, ii. 137.

† *Arseniate of Antimony.*—Nothing is known respecting the combinations of arsenic acid with either of the oxides of antimony. *Arseniate of Bismuth* falls as an insoluble white powder on adding arsenic acid to nitrate of bismuth. *Arseniate of Cobalt* is precipitated of a red colour by the addition of an alkaline arseniate to a soluble salt of cobalt. *Arseniate of Uranium* is thrown down by a straw colour when arseniate of potassa is added to nitrate of uranium.

‡ Philos. Trans. 1812, 188.

Iodide.

1411. *Iodide of Arsenic*, obtained by heating the metal with excess of iodine, is of a deep red colour, and volatile. When acted upon by water, it produces hydriodic and arsenic acids, whence it appears probable that it contains 1 proportional of arsenic and 3 of iodine.

Arsenic and hydrogen.

1412. *Arsenic and Hydrogen.*—When tin is dissolved in liquid arsenic acid, an inflammable gas is disengaged, as was observed by Scheele, consisting of hydrogen gas, holding arsenic in solution. It may be obtained, also, by adding metallic arsenic to a mixture of diluted sulphuric acid and zinc filings, or by acting on water with a triple alloy of arsenic, potassium and antimony. This alloy may be formed by heating strongly, for two hours, in a close crucible, two parts of antimony, two of cream of tartar, and one of white arsenic. When two or three drachms of this alloy are thrown quickly under a jar inverted in water, abundance of arsenuretted hydrogen is disengaged.[*] The greatest caution should be used to avoid its deleterious effects, which were fatal to the late M. Gehlen.[†] The gas may be collected over water, by which it is not sensibly absorbed.

1413. The specific gravity of this gas is liable to vary according to the mode by which it is procured. It has been found heaviest when obtained from a mixture of 4 parts of zinc, 1 of arsenic, and 3 of sulphuric acid, diluted with 4 or 5 of water. After standing a day over water, it deposits a small quantity of brown matter, which appears to be a *hydruret of arsenic*, and then it has a specific gravity of from 12 to 14, hydrogen being = 1. This is considerably heavier than the usual estimation. If the gas were composed of 1 proportional of arsenic and two of hydrogen, without condensation, 100 cubical inches should weigh 51,75 grains, and its specific gravity to hydrogen would be 20,7. But Gay-Lussac and Thenard[‡] have shown by decomposing it by tin, that 100 parts expand to 140, which would still increase its specific gravity, it being probable that 3 volumes of hydrogen are condensed into 2. It is probable, therefore, that the gas, hitherto described under the name of arsenuretted hydrogen, is a mixture of the real compound with hydrogen. B.

Properties.

1414. The gas obtained by the above described process is expanded in volume and deposits arsenic at high temperatures: exposure to intense cold is said to occasion its liquefaction. It

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[*] Quarterly Journal, xiii. 225.

[†] Ann. de Chim. 95, 110; and Ann. de Chim. et Phys. iii. 135.

[‡] *Recherches Physico-Chemiques*, Tom. i. p. 230. From the analogy of the other compounds of hydrogen and a combustible, there seems little doubt that it is a compound of

$$\left.\begin{array}{l}\text{1 volume arsenic vapour}\\ \text{1 volume hydrogen gas}\end{array}\right\}\text{ condensed into 1 volume.}$$

T. *First Principles*, i. 225.

smells strongly alliaceous; it extinguishes a taper, and burns with a pale blue flame, depositing arsenic and its oxide.*

Exp. Soap bubbles blown with a mixture of this and oxygen gases, burn with a blue flame, a white smoke, and a strong alliaceous smell.

Exp. If detonated with about 4 volumes of oxygen, arsenious acid and water are formed. A stream of arsenuretted hydrogen gas, issuing from a bladder fitted with a stop-cock, and set on fire in a large receiver filled with oxygen, burns with a blue flame of uncommon splendour.

According to Stromeyer,† it requires for its perfect combustion 0,72 parts by bulk of oxygen; but this is probably not sufficient to burn the arsenic.

1415. A solid compound of hydrogen and arsenic may be formed, by acting on water with an alloy of potassium and arsenic; and, of course, much less hydrogen gas is evolved, than the same weight of uncombined potassium would liberate from water. It is described by Gay-Lussac, as separating in chesnut-brown coloured flocks. There appears, indeed, to be a strong affinity between hydrogen and arsenic; for Berzelius found that the recently prepared metal, when distilled along with oxide of tin, gave a drop or two of water. It must, therefore, have yielded hydrogen to the oxygen of the oxide. H.

Exp. 1416. If bubbles of chlorine be passed up into a jar of arsenuretted hydrogen, standing over warm water, flame and explosion are often produced, muriatic acid is formed, and a brown hydruret is deposited; but if the gas be passed in the same way by successive bubbles into chlorine, no inflammation results, absorption takes place, and muriatic acid and chloride of arsenic are formed. If the chlorine be not very pure, and when the gases are cold, inflammation seldom follows their mixture.

1417. Chlorine, added to a mixture of sulphuretted with arsenuretted hydrogen, causes a deposit of red sulphuret of arsenic.

1418. Nitric acid suddenly decomposes arsenuretted hydrogen; water, oxide of arsenic, nitrous acid, and nitric oxide are the results.

Sulphuret. 1419. *Arsenic and Sulphur.*—By slowly fusing a mixture of metallic arsenic and sulphur, a *red sulphuret of arsenic* is obtained. It is crystallizable, and of a vitreous fracture: its specific gravity is 3.4. It is usually known under the name of *realgar,* and occurs *native* in Germany and Switzerland, in veins of primitive rocks and among volcanic matter. Its primitive form is an acute octoëdron.

Orpiment. 1420. If white arsenic be dissolved in muriatic acid, and precipitated by hydrosulphuret of ammonia, a fine yellow sulphuret of arsenic falls, which it appears only differs in form from realgar: it is usually called *orpiment.*

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* One cubic inch of the gas contains about one fourth of a grain of metallic arsenic. H.

† *Nicholson's Journal,* vol. xix.

Native.

1421. *Native Orpiment* is of a bright lemon or golden colour. It is generally massive and lamellar. It occurs both in primiive and secondary rocks in Suabia, Hungary, China, and South America.

Uses.

Orpiment is employed in calico-printing to de-oxygenate indigo, which thus becomes capable of attaching itself to the cloth. M. Braconnot recommends realgar for dyeing wool, silk, or otton, of a fine yellow colour. Having mixed one part of ulphur, 2 parts of white arsenic, and 5 of potash of commerce, melt them in a crucible at a heat near that of redness. The yellow mass thus obtained is to be dissolved in hot water, and filtered. It is then to be diluted, and sulphuric acid poured into t, of such strength as to produce a fleecy precipitate of a superb yellow colour. This dissolves with facility in ammonia, and gives a yellowish liquor, into which is to be poured an excess of ammonia for the purpose of discolouring it entirely. Goods plunged into this solution come out colourless, care being taken that no metallic vessels are used ; but they assume a fine yellow as the ammonia evaporates. The colour is durable, and resists acids but not alkalies. (*Ann. de Chim. et Phys.* xii. 98.)

Composition.

1422. Laugier* and Klaproth found

In realgar . . . . . . 100 arsenic united to 43,67 sulphur.

" orpiment . . . . . 100 " " 63,93 do.

It appears therefore, that orpiment and realgar, are both sulphurets of arsenic, containing sulphur in the proportions of 1 to 1½, or 2 to 3. In orpiment, it may be observed, the sulphur is nearly double the oxygen in the arsenious acid. To agree with atomic proportions it ought to be exactly so. H. 2. 54.†

Sulphate.

1423. Sulphuric acid is slowly decomposed when boiled upon arsenic. Sulphurous acid is evolved, and difficultly soluble crystalline grains of *sulphate of arsenic* are deposited as the solution cools.‡

Alloys.

1424. Arsenic forms alloys with most of the metals, and they are generally brittle. With potassium it forms a brownish compound, which, when put into water, evolves less hydrogen than pure potassium, in consequence of the formation of hydruret of arsenic. (1412.) With sodium, the alloy is either brown and of an earthy aspect, or grey and metallic, according to the proportions of the metals: water acts upon it as upon the former. (Gay-Lussac, and Thenard, *Recherches Physico-Chimiques.* Tom. 1.) The alloy of arsenic and manganese is not known. With iron, zinc, and tin, it forms white brittle compounds; with copper it forms a white malleable alloy; with lead, a brittle compound of lamellar texture; with antimony, the alloy is brittle, hard, and very fusible. It combines with bismuth, and probably with cobalt; but these alloys have not been examined.

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* Ann. de Chim. et Phys. v. 179.

† *Sulphuret of Arsenic and Iron* is found native in many parts of Europe. It is of a more silvery colour than iron pyrites, and when heated exhales the odour of arsenic. It is called *arsenical pyrites*, or *mis-pickel*.

‡ *Phosphuret of Arsenic* is formed by heating the metal, or its oxide, with phosphorus; it is grey and brittle. Neither the *Hypophosphite* nor *Phosphite of Arsenic* have been examined. *Phosphate of Arsenic* is formed in difficultly soluble crystalline grains, by boiling white arsenic in phosphoric acid.

Uses.

1425. Arsenic is used in a variety of the arts. It enters into metallic combinations, wherein a white colour is required. Glass manufacturers use it; but its effect on the composition of glass does not seem to be clearly explained. U. 179.

1426. The separation of arsenic from other metals may generally be accomplished by deflagration with nitre, by which it is acidified, and the arseniate of potassa may afterwards be washed out by hot water.

Methods of detecting arsenic.

1427. As arsenic, either accidentally or intentionally taken, is a very frequent cause of death, and often the subject of judicial inquiry, it becomes of importance to point out the most effectual modes of discovering its presence. Where arsenic proves fatal, it is very seldom found in the contents of the stomach after death, but is generally previously voided by vomiting or by stool; and we often can detect it in the matter thrown off the stomach, in the form of a white powder, subsiding in water. The inflammation of stomach which results is generally a secondary effect, and takes place equally, whether the poison be swallowed or applied to a wound.

If minute quantities of white powder be detected, however, in the stomach after death, or in the matter vomited, it is to be carefully collected, and treated as follows:

Concentrate by heat in a capsule the suspected poisonous solution, having previously filtered it if necessary. Indeed, if it be very much disguised with animal or vegetable matters, it is better first of all to evaporate to dryness, and by a few drops of nitric acid to dissipate the organic products. The clear liquid being now placed in the middle of a bit of glass, lines are to be drawn out from it in different directions. To one of these a particle of weak ammoniacal water being applied, weak nitrate of silver may then be brushed over it with a hair pencil. By placing the glass, in different lights, either over white paper or obliquely before the eye, the slightest change of tint will be perceived. Ammoniaco-acetate of copper should be applied to another filament of the drop, deut-acetate of iron to a third, weak ammoniaco-acetate of cobalt to a fourth, sulphuretted water to a fifth, lime-water to a sixth, a drop of violet syrup to a seventh, and two galvanic wires at the opposite edges of the whole.* Thus with one single drop of solution, many exact experiments may be performed.

But the chief, the decisive trial remains, which is to take a little of the dry matter, mix it with a small pinch of dry black flux, put it into a narrow glass tube sealed at one end, and after cleansing its sides with a feather, urge its bottom with a blow-pipe till it be distinctly red-hot for a minute. Then garlic fumes will be smelt, and a steel-lustred coating

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* A voltaic battery, made to act on a little arsenious solution placed on a bit of glass, developed metallic arsenic at the negative pole, and if this wire be copper, it will be whitened like tombac.

f metallic arsenic will be seen in the tube about one-fourth
f an inch above its bottom. Cut the tube across at that
oint by means of a fine file, detach the scale of arsenic with
he point of a penknife; put a fragment of it into the bottom of
small wine-glass along with a few drops of ammoniaco-acetate
f copper and triturate them well together for a few minutes
ith a round-headed glass rod. The mazarine blue colour will
on be transmuted into a lively grass-green, while the metallic
ale will vanish. Thus we distinguish perfectly between a
article of metallic arsenic and one of animalized charcoal.
nother particle of the scale may be placed between two smooth
d bright surfaces of copper, with a touch of fine oil; and
hilst they are firmly pressed together, exposed to a red-heat.
he tombac alloy will appear as a white stain. A third particle
ay be placed on a bit of heated metal, and held a little under
e nostrils, when the garlic odour will be recognized. No
anger can be apprehended, as the fragment need not exceed the
nth of a grain.

1428. It is to be observed that one or two of the precipitation
sts may be equivocal from admixtures of various substances.
hus tincture of ginger gives with the cupreous reagent a
reen precipitate;—and Dr Ure was at first led to suspect
om that appearance, that an empirical tincture, put into his
ands for examination, did contain arsenic. But a careful anal-
sis satisfied him of its genuineness. Tea covers arsenic from
he cupreous test. Such poisoned tea becomes by its addition
f an obscure olive or violet red, but yields scarcely any precip-
ate. Sulphuretted hydrogen, however, throws down a fine
ellow sulphuret of arsenic.*

1429. The true way of obviating all the sources of fallacy, is
evaporate carefully to dryness, and expose the residue to heat
a glass tube. The arsenic sublimes, and may be afterwards
perated on without ambiguity. M. Orfila has gone into ample
etails on the modifications produced by wine, coffee, tea, broth,
c. on arsenical tests, of which a good tabular abstract is given
n Mr Thomson's London Dispensatory. But it is evident that
he differences in these menstrua, as also in beers, are so great
s to render precipitations and changes of colour by reagents
ery unsatisfactory witnesses, in a case of life and death. Hence
he method of evaporation above described should never be
eglected. Should the arsenic be combined with oil, the mixture
ught to be boiled with water, and the oil then separated by the

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* Dr Cooper finds a solution of chromate of Potassa to be one of the best tests of arsenic. One drop
turned green by the fourth of a grain of arsenic, by two or three drops of Fowler's solution or any
her arsenite of potassa. The arsenious acid takes oxygen from the chromic, which is converted into
ide of chrome. To exhibit the effect, take five watch glasses, put on one, two or three drops of a
atery solution of white arsenic; on the second, as much arsenite of potassa; on the third, one fourth
a grain of white arsenic in substance; on the fourth, two or three drops of solution of corrosive sub-
nate; on the fifth, two or three drops of a solution of copper. Add to each three or four drops of a
lution of chromate of potassa. In half an hour a bright clean grass green colour will appear in num-
rs 1, 2, 3, unchangeable by ammonia; number 4 will instantly exhibit an orange precipitate; and num-
r 5 a green, which a drop of ammonia will instantly change to blue. Amer. Jour. of Science, 4, 166.

capillary action of wick-threads. If with resinous substances, these may be removed by oil of turpentine, not by alcohol, (as directed by Dr Black), which is a good solvent of arsenious acid. It may moreover be observed that both tea and coffee should be freed from their tannin by gelatin, which does not act on the arsenic previous to the use of reagents for the poison. When one part of arsenious acid in watery solution is added to ten parts of milk, the sulphuretted hydrogen present in the latter, occasions the white colour to pass into a canary yellow; the cupreous test gives it a slight green tint, and the nitrate of silver produces no visible change, though even more arsenic be added; but the hydro-sulphurets throw down a golden yellow, with the aid of a few drops of an acid. The liquid contained in the stomach of a rabbit poisoned with a solution of 3 grains of arsenious acid, afforded a white precipitate with nitrate of silver, greyish-white with lime-water, green with the ammoniaco-sulphate, and deep yellow with sulphuretted hydrogen water. U. 18.[*]

SECTION XXIV. *Molybdenum.*

How obtained.

1430. The sulphuret is the most common natural compound of this metal. To procure the metal, the native sulphuret is powdered and exposed under a red hot muffle, till converted into a grey powder, which is to be digested in ammonia and the solution filtered and evaporated to dryness. The residuum is dissolved in nitric acid, re-evaporated to dryness, and violently heated with charcoal.

Properties.

1431. Molybdenum has a whitish yellow colour, but its fracture is a whitish grey. It has not, hitherto, been obtained in any form, but that of small brittle grains. It is almost infusible by any artificial heat. Its specific gravity, according to Hielm, is 7.4; according to Bucholz, it is as high as 8.6.

Oxides,

1432. *Molybdenum and Oxygen.*—When exposed to heat and oxygen molybdenum is acidified, a white crystalline sublimate of *molybdic acid* being formed.

There are two other compounds of molybdenum with oxygen; the one *brownish black*, obtained by heating molybdic acid with charcoal; the other *blue*, and procured by immersing tin in solution of molybdic acid;

the black oxide consists of 47 M. + 8 oxygen (protoxide)
the blue (molybdous acid) 47 M. + 16 (Deutoxide)
the white (molybdic acid) 47 M. + 24 (Peroxide T.)

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[*] The reader is referred for further particulars on this subject to *Henry's Elements of Chemistry*, Vol. ii. p. 562, 9th edit.: to *Murray's System*, Vol. iii. p. 441, 4th edit.: to *Dr. Bostock's Paper*, in the *Edinb. Med. and Surg. Journal*, Vol. v. p. 166: to *Mr Hume's Essay*, in the *Phil. Mag.* Vol. xxxiii.; and *London Med. and Phys. Journal*, Vol. xxiii.: to *Dr Marcet's Paper*, in the *Medico-Chirurgical Transactions*, Vol. ii.: to *Mr Sylvester's Observations* in *Nicholson's Journal*, Vol. xxxiii; to *Beck's Medical Jurisprudence*, Vol. ii.: and to *Dr Traill's Paper*, in *Boston Journal of Philos.* 1. 543.

Mr Hatchett, in his *Experiments on the native Molybdates of Lead*, concludes the metal to be susceptible of four degrees of oxidizement.*

The above numbers are taken from the analyses of Bucholz, corrected by some experiments of my own (Brande) on the molybdic acid; our results are very nearly similar.

1433. The oxide, consisting of one atom of metal and one atom of oxygen, remains to be investigated. According to Dr Thomson, it may be obtained by dissolving molybdic acid in ammonia, evaporating to dryness, and exposing the dry mass, covered with charcoal powder, to a white heat in a covered crucible. The oxide will be found at the bottom of a crystallized shape, and of a copper brown colour. It is incapable of forming salts with acids.†

Molybdic acid.

1434. To obtain *molybdic acid*, the native sulphuret should be triturated, to reduce it, as far as possible to powder, and distilled with three or four parts of nitric acid, to dryness. This operation should be repeated, till the ore is converted into an uniform white mass, which consists of molybdic, nitric, and sulphuric acids; the two latter may be expelled by a red heat, in a platinum crucible, and the remaining molybdic acid repeatedly washed with boiling water, in which it is little soluble, will be nearly pure. It may be rendered perfectly pure by solution in ammonia, precipitation by nitric acid, and exposure to heat.

Properties.

1435. The molybdic acid, thus procured, is a white powder, of the specific gravity of 3,46, and requiring 960 parts of boiling water for its solution, which is yellow, reddens litmus, but has no sour taste. Heated to redness in an open vessel, it slowly sublimes, and condenses in brilliant yellowish scales. It dissolves in hot sulphuric acid, forming a solution which is colourless while hot, but on cooling acquires a blue colour, which is heightened by the addition of soda. Its muriatic solution is pale yellowish green, but becomes blue when saturated by potassa.—HATCHETT, *Phil. Trans.* 1796.

1436. The molybdous and molybdic acids unite with salifiable bases, and form distinct classes of salts. The latter acid is changed into the former, by some of the metals that powerfully attract oxygen. Thus a solution of molybdic acid, in which a small rod of tin or zinc is immersed, becomes blue, in consequence of the partial disoxygenation of the acid; and on the same principle recent muriate of tin throws down from molybdate of potassa, a fine blue precipitate. The molybdic acid decomposes the nitrates of silver, mercury, and lead; and the nitrate and muriate of baryta. H. 2. 57.

Molybdate of ammonia.

1437. *Molybdate of Ammonia* is not crystallizable, and when heated to redness the ammonia is driven off, and the acid converted into oxide of molybdenum.—BUCHOLZ, *Gehlen's Journal*, iv. 616.

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* Phil. Trans. 1796.

† System of Chemistry, i. 436.

— of potassa. 1438. *Molybdate of Potassa* is formed by digesting the acid in potassa; or by heating to redness two parts of nitre with one of molybdic acid, and lixiviating the mass. The solution yields small rhomboidal crystals by evaporation, and affords a precipitate of molybdic acid, to muriatic, nitric, and sulphuric acids.

— of soda. 1439. *Molybdate of Soda* is more soluble than molybdate of potassa, and furnishes permanent and transparent crystals. In obtaining both these salts, a deposit of a yellowish powder ensues, which is probably a *bimolybdate* of potassa and of soda.

— of lead. 1440. *Native Molybdate of Lead* occurs principally in crystals of different shades of yellow. According to Mr Hatchett's analysis* it contains 38 molybdic acid + 58,4 oxide of lead; and these numbers closely correspond with its theoretical composition, which should be 1 proportional of molybdic acid = 71 + 1 proportional of oxide of lead = 112.

— of silver. 1441. *Molybdate of silver, of mercury, of lead*, and *of nickel*, may be procured by adding molybdic acid to the respective nitrates of these metals.

Sulphuret. 1442. *Sulphuret of Molybdenum* is a sectile compound of a metallic lustre, composed of 47 M. + 32 S.

The *native sulphuret* rarely occurs crystallized; generally massive, and made up of easily separable laminæ. It is soft and unctuous to the touch, and in colour much like lead. It is found in primitive rocks; generally in granite, and with quartz.

SECTION XXV. *Chromium.*

Discovery. 1443. CHROMIUM was discovered by Vauquelin in 1797. It may be obtained by intensely igniting its oxide with charcoal. Its colour resembles that of iron, and its specific gravity is 5,9. It is brittle and difficult of fusion.

Oxides. 1444. *Chromium and Oxygen.*—When chromium is exposed to the action of heat and air, it combines with oxygen, and a *green protoxide* is obtained. This oxide easily dissolves in acids.

1445. *Native Protoxide of Chromium* has been found in France, in the department of the Rhone, in the form of a green incrustation. It is the colouring matter of the emerald, and exists in a few other minerals.

1446. When nitrate of chromium is decomposed at a red heat, an insoluble *brown deutoxide* is formed. It does not dissolve in the acids; but when heated with muriatic acid, chlorine is evolved, and a muriate containing the protoxide, is formed.

Peroxide or chromic acid. 1447. *Peroxide of Chromium*, or *Chromic acid*, is most easily procured by the decomposition of the native *chromate of lead*, which may be effected by reducing it to a very fine powder, and boiling it in a solution of potassa or soda. An orange-coloured solution of the alkaline chromate is thus formed, to which sulphuric acid is to be added. On evaporation crystals of chromic acid are formed, along with the sulphate of soda or of potassa. Or the acid may be obtained by adding nitrate of baryta to the chromate of potassa and subsequently decomposing the chromate of baryta which falls by sulphuric acid.

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* Phil. Trans. 1796.

Process for obtaining.

Chromate of iron, however, from the great plenty in which it is found, is a much cheaper source of chromic acid. After reducing it to fine powder, it is to be mixed with half its weight of nitrate of potassa, and heated strongly for an hour or two in a crucible. The mass is to be repeatedly digested with water, and the coloured liquids, which are slightly alkaline, saturated with nitric acid, and concentrated by evaporation, till no more crystals of nitre can be obtained from them. The yellow liquid being now set aside for a week or two, deposits a copious crop of yellow crystals in small needles. These are to be separated, dissolved in water, and crystallized over again. They are then sufficiently pure chromate of potassa. From the solution of these crystals, or indeed from the yellow liquid, nitrate of mercury throws down a red powder, which is chromate of mercury. When sufficiently heated, this compound is decomposed, and yields chromic acid or chromic oxide, from either of which metallic chromium may be obtained by heating it violently with charcoal in a crucible. H. 2. 58.

Properties.

1448. Chromic acid is of a red colour; its taste is sour and metallic, and it may be obtained from its aqueous solutions in prismatic crystals, of a ruby colour. When heated red hot, it gives out a portion of oxygen, and becomes the green protoxide; it imparts colour to the ruby.

Chromate of iron,

1449. *Native Chromate of Iron* has been found in small crystalline grains, of an octoëdral form. It commonly occurs massive, of a black colour, with a slight metallic lustre, and hard enough to cut glass. It has been found in Siberia, France, and America, and has become useful in the arts, as a source of some fine pigments.

— of lead.

1450. *Native Chromate of Lead* is a very rare mineral, hitherto only found in the Uralian mountains in Siberia; it occurs in crystals of a fine orange red colour.

Equivalent number.

1451. The composition of the oxide and acid of chromium has not been determined by direct experiments; but from the analysis of chromates of lead and baryta, it would appear that 52 is the equivalent number for chromic acid. Now Berzelius assigns to the acid double the quantity of oxygen that exists in the oxide, and it is probable that chromic acid consists of one atom of metal + 3 atoms of oxygen. Deducting 24 from 52, we obtain 28 for the atom of chromium, and $28 + 12 = 40$, for that of the protoxide. H.

Chromate of potassa.

1452. *Chromate of Potassa* crystallizes in four-sided slender prisms, terminated by dihedral summits. Their colour is an intense lemon yellow, with a slight shade of orange. The colouring power of this salt is so great that 1 grain in 40,000 grains of water forms a solution which is perceptibly yellow. Its taste is cooling, bitter, and very disagreeable, remaining long in the mouth. One hundred parts of water at 60° dissolve about 48 parts, but boiling water dissolves almost any quantity. It is insoluble in alcohol. Its solution in water decomposes most of the metallic salts; those of lead of a beautiful yellow colour, now much used as a pigment; those of mercury of a fine red; copper and iron reddish brown; silver, dark red. According to Dr Thomson, chromate of potassa is composed of

1 atom of chromic acid . . . . = 52
1 do. of potassa . . . . = 48

100 H.

Bi-chromate. 1453. *Bi-chromate of Potassa.*—When to a solution of these crystals in water, such a quantity of sulphuric acid is added, as to give the liquor a sour taste, and it is set aside for 24 hours, small regular needles are deposited; or sometimes rectangular tables of considerable size, and of a beautiful orange red colour. These crystals are the *bi-chromate of potassa.* They are much less soluble in water than the chromate; for 100 parts at 60° Fahr. dissolve only about 10 parts. The solution has an intense orange colour, and reddens vegetable blues. This salt is composed of

2 atoms of chromic acid = 104 68,421
1 atom of potassa . . . = 48 31,579

152 100. H. 2. 59.

Characters of the chromates of ammonia and soda, &c. 1454. The chromates of ammonia, soda, lime, and magnesia are soluble and crystallizable, and of an orange colour. The chromates of baryta and strontia are difficultly soluble, and may be formed by adding chromate of potassa or soda to their soluble saline compounds. The other insoluble metallic chromates may be formed in the same way, and their colours, which are various and beautiful, often enable us to judge of the nature of the metal present. Thus chromate of soda forms insoluble precipitates in solutions of silver, mercury, lead, copper, iron and uranium; the colours are crimson, red, orange or yellow, apple-green, brown, and yellow. It forms no precipitate in solutions of nickel, zinc, tin, cobalt, gold, or platinum; whence perhaps, it may be inferred, that the chromates of the latter metals are soluble.

The chromates are decomposed by muriatic, nitric, and sulphuric acids. Muriatic acid, heated with the chromates, evolves chlorine, the chromic acid being reduced to the state of oxide.*

1455. The principal use to which chromium has been applied,
Uses. is the preparation of the beautiful pigment, chromate of lead, known in commerce by the name of *chrome yellow.* It is pre-

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* The most correct details respecting the chromates that have been published are to be found in Vauquelin's *Essay Annales de Chimie*, lxx.

pared by mixing the solutions of chromate of potassa and nitrate or acetate of lead. Nineteen parts of bi-chromate of potassa decompose 41,5 of dry nitrate of lead. The insoluble compound consists of 1 atom of chromic acid + 1 atom of protoxide of lead. (Thomson.) It appears probable, also, from the experiments of Lassaigne[*] that chromium admits of being successfully applied to the arts of dyeing and calico-printing; and in the latter very striking effects have already been produced on the large scale. H. The green oxide of chromium is occasionally used in porcelain and enamel painting.

SECTION XXVI. *Tungsten.*

Origin of the name.

1456. TUNGSTEN, or Tungstenum, signifies a heavy stone, and is a name given by the Swedes to a mineral, which Scheele found to contain a peculiar metal, as he supposed in the state of an acid, united with lime. The same metallic substance was afterwards found by Don d'Elhuyarts united with iron and manganese in wolfram.[†]

1457. The metal is obtained by exposing a mixture of tungstic acid and charcoal to a strong heat. It is difficult of fusion, very hard, brittle, and of an iron colour. Its specific gravity is 17,5. By the action of heat and air, tungsten is converted into an oxide which is of a yellow colour. It has been called by some *Scheelium*, by others *wolframium*.

Wolfram, decomposition of.

Wolfram is found in primitive countries generally accompanying tin ores; its colour is brownish black; it occurs massive and crystallized, its primitive form being a rectangular parallelopiped. It abounds in Cornwall. It may be decomposed by ignition with three times its weight of nitre; the fused mass, digested in boiling water and filtered, furnishes a solution, which upon the addition of muriatic acid, gives a precipitate regarded by Scheele as tungstic acid, but which in fact is a compound of muriatic and tungstic acids and potassa. Dissolve this in boiling carbonate of potassa, precipitate by muriatic acid, wash the precipitate, and digest it in nitric acid. Then wash and dry it, and it is pure tungstic acid.[‡]

Tungstate of lime.

1458. *Native Tungstate of Lime* is a whitish semi-transparent substance, found in England, Saxony, Bohemia, and Sweden, and occurring crystallized and massive. Its most usual form is the octoëdron. It may be decomposed by fusion with four parts of carbonate of potassa, the fused mass is digested in about twelve parts of boiling water, and filtered. Nitric acid precipitates the peroxide.

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[*] Ann. de Chim. et Phys. xiv. 299, xv. 76, and xvi. 409.

[†] Ann. de Chim. et Phys. iii. 161.

[‡] Bucholz, as quoted by Thomson, *System*, ii. 122.

Tungstate of lime was found by Klaproth to consist of 77,75 acid + 22,25 lime; but Berzelius states its components to be 80,4 acid + 19,6 base.

Oxides. 1459. There are two oxides of tungsten, the brown, and the yellow or *tungstic acid.*

1460. The brown oxide is formed by transmitting hydrogen gas over tungstic acid in an ignited glass tube. It takes fire when heated in the air, and burns like tinder, passing into tungstic acid.

This oxide appears to be composed of 16,564 oxygen and 100 metal.[*] It does not unite with acids or bases.

Tungstic acid. Tungstic acid may be obtained from wolfram by the following process. The wolfram, cleared from its siliceous gangue, and pulverised, is heated in a matrass with five or six times its weight of muriatic acid, for half an hour. The oxides of iron and manganese being thus dissolved, we obtain the tungstic acid under the form of a yellow powder. After washing it repeatedly with water, it is digested in an excess of liquid ammonia, and heated, which dissolves it completely. The liquor is filtered and evaporated to dryness in a capsule. The dry residue being ignited, the ammonia flies off, and pure tungstic acid remains. If the whole of the wolfram has not been decomposed, it must be subjected to muriatic acid again.[†]

Properties. 1461. *Tungstic Acid*, or *Peroxide of Tungsten*, is tasteless and insoluble in water; its specific gravity is 6. When violently heated, it becomes green, grey, and black, probably from the loss of oxygen. It combines with several of the metallic oxides, and was found by Guyton to give considerable permanence to vegetable colours; hence it probably might prove useful in the art of dyeing, were it more abundantly procurable.

Composition. The tungstic acid is composed, according to Bucholz of 100 tungsten and 25 oxygen,[‡] or 80 + 20; supposing the acid to consist of an atom of metal and 3 atoms of oxygen this would give 96 for the equivalent of tungsten, and 120 for that of tungstic acid. H.

Chlorides. 1462. *Tungsten and Chlorine.* Sir H. Davy found that metallic tungsten burns with a deep red light when heated in chlorine, and produces a white substance which is decomposed by the action of water, into tungstic and muriatic acids. M. Wöhler[§] has shown the existence of three compounds of chlorine and tungsten.

When metallic tungsten is heated in chlorine, it takes fire and burns into a chloride, with a minimum of chlorine. The compound appears sometimes as delicate fine needles, of a deep red colour resembling wool, but more frequently as a fused deep-red compact mass, with the brilliant fracture of cinnabar.

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[*] Berzelius as quoted by Thenard, 2. 356, and Ann. de Chim. et Phys. xvii. 15.

[†] Thenard, *Traite*, 2. 400 edit 4. U. 114.

[‡] Thenard, 2. 401.

[§] Ann. de Chim. 29. 43.—Philos. Mag. 66. 263.

hen heated, it fuses, boils, and yields a red vapour. In water gradually decomposes, producing muriatic acid and oxide of igsten. This compound dissolves in solution of pure potassa, olving hydrogen, forming chloride of potassium, and tungte of potassa. Similar effects take place in ammonia.

1463. When the black oxide is heated in chlorine in a tube, nbustion takes place, dense fumes are formed, which ultitely produce a thick sublimate of white scales, resembling in earance native boracic acid; this is the *perchloride of tungn.* In the air it gradually becomes tungstic and muriatic ds: the change is more rapid in water. It is volatile at a r temperature, without previously fusing. Heated on platina l it is also decomposed into muriatic and tungstic acid.

1464. The third compound, on the composition of which no periment has been made, is generally formed at the same e with the perchloride, but in small quantity. It has been tained by heating the sulphuret of tungsten in chlorine. is is the most beautiful compound of all, existing in long nsparent crystals, of a fine red colour; it readily fuses, and on oling crystallizes in long needles. It is volatile, and instantly inges in contact with the air into tungstic acid. Thrown into ter it swells like caustic lime, disengages heat, a slight noise heard, and it is instantly changed into tungstic acid.*

1465. Berzelius has lately examined the *sulphuret of tungn,* with the view of determining the capacity of saturation of it metal. He heated together one part of powdered tungstic d, and four of sulphuret of mercury. The latter metal was pelled and a blackish grey compound remained, not unlike phuret of copper. On analysis it afforded Sulphuret.

			Atoms.
Tungsten	74,891	100	1 = 96
Sulphur	25,109	35,53	2 = 34
	100,		130

One hundred parts of the sulphuret, calcined so as to expel sulphur and oxidize the metal, gave 93,5 of tungstic acid; l as that quantity of acid must contain 74,891 metal, 100 uld contain 80,09, which agrees with the experiment of cholz. It may be remarked, that the sulphur in the sulphuis rather more than double the oxygen in the new oxide ained by Berzelius, but the difference is not greater than may accounted for by the unavoidable errors of the experiments. nsisting of two atoms of sulphur and one of metal, it is in t to be considered as a bi-sulphuret of tungsten. H. 2. 63.

Some of the tungstates have been examined by Scheele, and ers by Vauquelin and Hecht,† but their history remains very perfect.

1466. *Tungstate of Ammonia* is procured in crystalline les, of a metallic taste, by digesting the acid in ammonia or its Tungstate of ammonia.

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* M. Wöhler.

† Journal des Mines, No. 19.

carbonate. It contains, according to Vauquelin, 78 of acid, and 22 ammonia and water.

Tungstate of potassa.

1467. *Tungstate of Potassa* is uncrystallizable and deliquescent. The acids occasion precipitates in its solution, which are triple compounds of tungstic acid, potassa, and the acid used as precipitant. The *Nitrotungstate of Potassa* is the salt originally described by Scheele as tungstic acid. It dissolves in 20 parts of water, at 212°, and reddens litmus.

— of soda,

1468. *Tungstate of Soda* crystallizes in hexaëdral tables, soluble in 4 of cold, and 2 parts of boiling water, and of an acrid taste. Sulphuric, nitric, and muriatic acids occasion precipitates, as in the tungstate of potassa.

— of lime,

1469. *Tungstate of Lime*, *of Baryta*, and *of Strontia*, are insoluble white compounds.

— of magnesia.

1470. *Tungstate of Magnesia* is obtained by boiling the acid with magnesia, filtering, and evaporating; it crystallizes in pearly scales. The acids produce precipitates of triple compounds in its solution.

— of manganese, &c.

1471. *Tungstate of Manganese*, formed by adding tungstate of potassa to muriate of manganese, is an insoluble white powder.* *Tungstate of Iron* is also insoluble: *Tungstate of Zinc* and *of Tin* have not been examined, nor have any of the remaining tungstates been examined in their pure state.

The remaining compounds of tungsten have scarcely been investigated, and appear of little interest or importance.

SECTION XXVII. *Columbium.*

Discovery.

1472. THIS metal was discovered in 1801, by Mr Hatchett, in a black mineral in the British museum, which had been sent by Gov. Winthrop to Sir Hans Sloane, from the vicinity of New-London in Connecticut.

By alternate fusion with potassa, and digestion in muriatic acid, the mineral was decomposed; the acid combining with oxide of iron, and the alkali with a peculiar metallic acid, separable by the addition of diluted nitric acid, which threw down a copious white sediment.

Tantalite and yttro-tantalite.

1473. A metal analogous in its properties to columbium, was discovered by Mr Ekeberg, a Swedish chemist, in two different fossils, called Tantalite and Yttro-tantalite. To this metal he gave the name of *tantalum*.

1474. Tantalite is chiefly found in octoëdral crystals, and in masses of a black or grey colour, in Finland. Its specific gravity is 7.9, and it contains, according to Ekeberg, 80 oxide of columbium; 12 oxide of iron; 8 oxide of manganese.

Tantalite.

1475. Yttro-tantalite is found in Ytterby, in Sweden. It contains about 45 per cent. of oxide of columbium. Its colour is dark grey, its lustre shining and somewhat metallic.

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* John, Gehlen's Journal, iv.

Dr Wollaston examined these and the original mineral in the British museum, and demonstrated the identity of columbium and tantalum. As the former name was given to this body by its original discoverer, it is here retained.

Process for obtaining columbium.

1476. Columbium may be procured from columbite or tantalite, by the following process: Mix 5 parts of the finely-powdered mineral with 25 of carbonate of potassa, and 10 of borax; fuse the mixture, and when cold digest it in muriatic acid; this dissolves every thing except the oxide of columbium, which remains in the form of a white powder.* From 5 grains of columbite, Dr Wollaston obtained

Oxide of columbium	4 grains
——— iron	$\frac{3}{4}$
——— manganese	$\frac{1}{4}$

From 5 grains of tantalite he procured

Oxide of columbium	$4\frac{1}{4}$ grains
——— iron	$\frac{1}{2}$
——— manganese	$\frac{2}{16}$

Berzelius's method.

1477. Berzelius is the only person who has obtained metallic columbium. His method consisted in introducing the oxide, which had previously been strongly heated, into a cavity about one inch and a half deep, and of the diameter of a goose-quill, artificially formed in a piece of charcoal. To this cavity a stopper of charcoal was fitted, and the whole inclosed in a Hessian crucible was exposed to a violent fire during an hour. H. 2. 66. He describes it as having the colour of iron, very hard and brittle, and burning at a red heat into a whitish oxide.

White oxide.

1478. The characters of *white oxide of columbium* are very well marked. It is nearly insoluble in muriatic, nitric, and sulphuric acids; it is very soluble in potassa, and carbonate of potassa; 8 grains of the latter, fused with one of the oxide render it soluble in water. It is much less soluble in soda, and only retained while hot. From the readiness with which this oxide combines with potassa Mr Hatchett called it *columbic acid.*

Columbate of potassa.

1479. *Columbate of Potassa,* as appears from Mr Hatchett's experiments, forms white glittering scales, like boracic acid. Acids precipitate the columbic acid from this solution.

1480. Infusion of galls, added to the solution of columbate of potassa produces a very characteristic orange-coloured precipitate. Neither ferro-cyanate of potassa, nor hydrosulphurets, occasion any change.

There is a character very peculiar to the oxide of columbium, which is its ready solubility, in tartaric, citric, and oxalic acids. In all these cases the newly precipitated oxide must be used, for when dried, it becomes very intractable.

1481. According to Berzelius, 100 parts of columbium combine with 5,485 of oxygen; so that the representative of the metal will be 144, and that of the oxide 144 + 8 = 152.

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* Wollaston, *Phil. Trans.* 1809, p. 248.

SECTION XXVIII. *Nickel.*

To obtain pure nickel.

1482. NICKEL is found native; combined with arsenic; and with arsenic acid. To obtain pure nickel, Dr Thomson has employed with success the following process, the outline of which was suggested to him by Dr Wollaston. Reduce to coarse powder a quantity of the brittle reddish alloy, known in commerce by the name of *speiss*, which is chiefly a compound of arsenic and nickel; pour upon it a quantity of dilute sulphuric acid; place the mixture in a Wedgwood's evaporating dish, and add, at intervals, the quantity of nitric acid requisite to enable the acid to act upon the speiss. By this operation, a deep grass green liquid is obtained, while a considerable quantity of arsenious acid remains undissolved. Decant the green liquid, and evaporate it till it is sufficiently concentrated to yield crystals, when it is to be set aside in a cool place. A deposite of beautiful crystals of sulphate of nickel will be obtained. By concentrating the liquid still farther, more crystals of sulphate of nickel will fall; but after a certain time the liquid, though its colour continues dark green, refuses to yield any more crystals of the sulphate. When evaporated still farther and set aside, a very abundant deposite is made of an apple-green salt, which adheres very firmly to the evaporating dish, and which is a double salt consisting of sulphate of nickel and arseniate of nickel. Dissolve this in water, and pass a current of sulphuretted hydrogen gas through it, as long as any precipitate appears. Filter and evaporate again, when it will still be converted into an apple-green matter. When this is dissolved in water, the liquid becomes opaque, owing to the separation of a quantity of arsenious acid. The liquid, being filtered and again evaporated, yields crystals of true sulphate of nickel. For greater security, the whole of the sulphate of nickel, which has been obtained, may be re-dissolved and crystallized a second time.

The pure sulphate is next to be dissolved in water, and decomposed by carbonate of soda. The carbonate of nickel, when well washed and dried, is a light green-coloured powder. To reduce the metal, this carbonate is to be made up into balls with a little oil, which is to be put into a Hessian crucible, and surrounded with powdered charcoal. A cover is to be luted on the crucible, and it is to be exposed, for two hours, to the strongest heat that can be raised in a melting furnace. By this process, Dr Thomson has always obtained a button of pure nickel in the metallic state.*

Dr Clarke, of Cambridge, (Eng.) has also shown that the crystals of nitrate of nickel, when placed in a cavity scooped out of a piece of charcoal, and exposed to the oxy-hydrogen blowpipe, afford a bead of metallic nickel. This, however, is a process obviously adapted to yield only very minute quantities of nickel.* H. 2. 155.

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* Ann. of Philos xiv. 144.

Properties. 1483. Nickel is a white metal, which acts upon the magnetic needle, and is itself capable of becoming a magnet. It is difficultly fusible, but absorbs oxygen readily when heated red-hot. It is malleable, and its specific gravity is about 8,5.

Oxides. 1484. Nickel appears to be susceptible of two different states of oxidation. By long exposure to a red heat, with free access of air, it is converted into a dark brown oxide, which is still magnetic. In oxygen gas it burns vividly, and throws out sparks.

Protoxide. 1485. *The protoxide of nickel* is formed whenever nickel is dissolved in acids; it is of an ash-grey colour, dissolves in acids and forms green solutions, from which alkalies throw down an apple green *hydrate.* This oxide, obtained by dissolving nickel in nitric acid, and gently calcining the product, consists of

			Atoms.	
Nickel	83,34	100	1	= 40
Oxygen	16,66	20	1	= 8
	100,	120		48

Deutoxide. 1486. The *deutoxide* is obtained by the action of chlorine on the protoxide, as pointed out by Thenard; a current of chlorine gas being passed through water in which the hydrate is suspended. It is of a brilliant black colour, and has many analogies with peroxide of manganese, like which it gives off oxygen at a red heat and evolves chlorine from muriatic acid. It is constituted of

			Atoms.	
Nickel	71,43	100	1	= 40
Oxygen	28,57	40	2	= 16
	100,	140		56

Chlorides. 1487. The *protochloride of nickel*, obtained by evaporating to dryness a solution of nickel in muriatic acid, consists of

			Atoms.	
Nickel	52,64	100	1	= 40
Chlorine	47,36	90	1	= 36
	100,	190		76

1488. The *deuto-chloride* which sublimes when the foregoing compound is heated, in light shining yellow crystals, is formed of

			Atoms.	
Nickel	35,72	100	1	= 40
Chlorine	64,28	180	2	= 72
	100,	280		72

All these numbers concur in fixing the equivalent number of nickel at 40.† Dr Thomson from the composition of the sulphate of nickel makes the number for the metal 26, hydrogen being 1.*

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* Ann. of Philos. xiv. p. 148.

† Lassaigne as quoted by Henry, 2. 370.

Iodide.

1489. *Iodide of Nickel* may be formed by adding solution of hydriodate of potassa to sulphate or nitrate of nickel; it is of a greenish yellow colour, and insoluble.

Action of nitric and nitro-muriatic acid.

1490. The appropriate solvents of nickel are the nitric and nitro-muriatic acids. The nitric solution has a beautiful grass-green colour, and on evaporation affords rhomboidal crystals. Carbonate of potassa throws down an apple-green precipitate, which assumes a dark grey colour when heated. The fixed alkalies occasion a bulky greenish white precipitate, which is a hydrate or hydro-oxide of nickel, composed of 76 per cent of the protoxide and 24 water.

When pure ammonia is added to nitrate of nickel a precipitate is formed, resembling that which is separated by ammonia from a solution of copper, but not of so deep a hue. This colour changes, in an hour or two, to an amethyst red, and to a violet; which colours are converted to apple-green by an acid, and again to blue and violet by ammonia. If the precipitate retain its blue colour, the presence of copper is indicated.† This precipitate, which is a hydrate, is re-dissolved by an excess of ammonia; and by this property the oxide of nickel may be separated, in analyses, from those of almost all other metals. H. 2. 158.

Nitrate.

1491. *Nitrate of Nickel* is a green deliquescent salt, difficultly crystallizable in rhomboids. The analyses of this salt are much at variance, but it probably consists of 1 proportional of each of its components. The crystals contain 3 proportionals of water. B.

Sulphuret.

1492. *Sulphuret of Nickel.* Solutions of all the salts of nickel are decomposed by alkaline hydro-sulphurets, with which they form black precipitates; but sulphuretted hydrogen has no effect on them. Nickel, may, however, be combined directly with sulphur by fusion, and forms a grey compound with a metallic lustre.

The sulphuret consists of

Composition.

			Atom.	
Nickel	71,43	100	1 =	40
Sulphur	28,57	40	1 =	16
	100	140		56 H. 2. 671.

Sulphate.

1493. *Sulphate of Nickel* is formed by digesting the oxide in dilute sulphuric acid. A bright green solution is formed, which affords quadrangular prismatic crystals, soluble in about 3 parts of water at 60°, and which effloresce by exposure. Their taste is sweet and astringent. This salt is also obtained by heating common nickel in sulphuric acid with the occasional addition of nitric acid.

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* First Princip. i. 358.

† Richter, in *Nicholson's Journal*, xii.

The crystallized sulphate of nickel contains 7 proportionals of water, 1 proportional of oxide, and 1 proportional of acid.

1494. *Sulphate of Ammonia and Nickel* is formed by evaporating a mixed solution of ammonia, and sulphate of nickel; it forms four-sided prismatic crystals.

Sulphate of potassa and nickel.

1495. *Sulphate of Potassa and Nickel* is obtained by adding potassa to sulphate of nickel (not in excess,) filtering and evaporating. It forms green rhomboidal crystals.

1496. *Sulphate of Nickel and Iron* is formed by dissolving the mixed protoxides in sulphuric acid. It is a green efflorescent salt, in tabular crystals.

1497. Sulphuretted hydrogen and hydrosulphuret of ammonia produce a black precipitate of *hydrosulphuretted oxide of nickel,* when added to the solution of the metal.

Phosphate.

1498. *Phosphate of Nickel* being nearly insoluble, is precipitated, upon adding phosphate of soda to a solution of nickel. It is of a pale green colour.

Carbonate.

1499. *Carbonate of Nickel* is precipitated in the form of a green powder, when carbonate of potassa is added to sulphate of nickel. It is probably a compound of 1 proportional of each of its components.*

1500. Ferrocyanate of potassa occasions a very characteristic pale grey precipitate in dilute solutions of nickel: in concentrated solutions the precipitate is pale green.

1501. Arseniate of potassa, dropped into nitrate of nickel occasions the precipitation of a pale green *arseniate of nickel.*

Characters of salts of nickel.

1502. The salts of nickel are distinguished by the fine green colour of their solutions, and by affording a green precipitate with ammonia, soluble in excess of that alkali, when it assumes a blue colour. The yellow green precipitate afforded by hydriodate of potassa is very characteristic of nickel; but the nicest test of its presence is the ferrocyanate of potassa, which produces a pale grey or greenish white precipitate in all the solutions of the metal.

Alloys.

1503. Of the *Alloys of Nickel* that with iron forms the principal metallic ingredient in those lapideous masses, which, in different countries, have fallen upon our globe, and which have been termed *aërolites*, or *meteoric stones.*†

1504. In meteoric iron the proportion of nickel varies considerably. In a specimen from the arctic region Mr Brande found 3,2 per cent.‡ In that from Siberia Mr Children found nearly 10 per cent. The analysis may be performed by solution in nitro-muriatic acid; the iron is thrown down by excess of ammonia in the state of peroxide, of which 100 grains indicate 70 of metallic iron; it is separated by filtration, washed and dried, and on evaporating the filtrated liquor and heating its dry residue red-hot, the oxide of nickel is obtained, which should be re-dissolved in nitric acid and precipitated by pure potassa, the mixture being boiled for a few seconds. 100 grains of this oxide of nickel are equal to 79 of metallic nickel.*

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* *Borate of Nickel* is a pale green insoluble compound.

† For an account of meteoric stones, masses of iron, &c. which have fallen from the heavens, from the earliest period down to 1819, see Edin. Philos. Jour. Vol. i. p. 221.—See also Cleaveland's Mineralogy, p. 773.

‡ Quarterly Journal, vi. 369.

1505. Meteoric iron has been imitated by fusing iron with nickel. The alloy of 90 iron with 10 nickel is of a whitish yellow cast, and not so malleable as pure iron. The alloy with 3 per cent. of nickel is perfectly malleable and whiter than iron. These alloys are less disposed to rust than pure iron, but nickel alloyed with steel increases the tendency to rust.†

1506. The remaining alloys of nickel have been little examined. Nothing is known of its compounds with potassium, sodium, manganese, zinc, or tin. With copper it forms a hard white alloy, which appears to be the *white copper* of the Chinese. Its other alloys have not been examined.

Dr Wollaston's method of detecting nickel in iron.

1507. To detect, in a general way, the presence of nickel in iron, Dr Wollaston recommends that a small quantity (which need not exceed $\frac{1}{100}$ of a grain) should be filed from the specimen, dissolved in a drop of nitric acid; and evaporated to dryness. A drop or two of pure liquid ammonia, added to the dry mass and gently warmed, dissolves any nickel that may be present. The transparent part of the fluid is then to be led, by the end of a glass rod, to a small distance from the precipitated oxide of iron; and the addition of a drop of triple prussiate of potassa detects the presence of nickel by the appearance of a milky cloud, which is not discernible in the solution of a similar quantity of common wrought iron treated in the same manner. H. 2. 160.

SECTION XXIX. *Mercury*.

1508. Mercury, or quicksilver, is the only one of the metals that retains a fluid form at the ordinary temperature of the atmosphere.

Ore.

The principal ore of this metal is the sulphuret, or *native cinnabar*, from which the mercury is separated by distillation with quicklime or iron filings.

Boiling point.

1509. Mercury is a brilliant white metal, having much of the colour of silver, whence the terms *hydrargyrum*, *argentum vivum*, and *quicksilver*. It has been known from very remote ages. It boils and becomes vapour at 670°. It also rises in vapour in small portions at the common temperature of the atmosphere, particularly in a vacuum.

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* Children, *Quarterly Journal*, ix. 324.

† Stodart and Faraday, *Quarterly Journal*.

Freezing.

1510. When the temperature of mercury is reduced to about 39° or 40° below zero of Fahrenheit, it becomes solid (132.) and malleable.

By congelation it acquires an increase of specific gravity; and, therefore, unlike other metals, the congealed portion sinks to the bottom of a fluid mass of mercury. Its specific gravity, at 47° above 0 of Fahrenheit, being 13, 545, it was found increased by congelation, in an experiment of Mr Biddle, to 15,612, or about one-seventh.

Adulteration, how detected.

1511. Mercury is sometimes adulterated with the alloy of lead and bismuth, a fraud easily detected by the want of its due fluidity, and by its not being perfectly volatile, but leaving a residuum when boiled in a platinum or iron spoon. The best method of purifying mercury is to re-distil it in an iron retort.*

Oxides.

1512. *Mercury and Oxygen.*—Mercury is not oxidized, when pure, at the ordinary temperature of the atmosphere; but preserves the lustre of its surface unchanged for a considerable time. There are several methods, however, by which it may be brought to combine with oxygen.

Protoxide.

1513. There are two oxides of mercury. The *black*, or *protoxide*, may be obtained by long agitation of the metal in contact with oxygen, or by washing the *chloride of mercury* (calomel) with hot lime-water. It is insipid, and insoluble in water, and was called in old pharmacy, *Ethiops per se.*† In this, the oxide is mixed, however, with much metallic mercury.

Peroxide.

How obtained.

1514. The *red* or *peroxide* of mercury is produced by exposing the metal, heated nearly to its boiling point, to the action of air. It becomes coated with reddish brown scales, spangles, and crystals, and is ultimately entirely converted into a red shining mass, called in old pharmaceutical works, *precipitate per se*, or *calcined mercury*. It is the *hydrargyri oxidum rubrum* of the present *London Pharmacopœia*. It is most easily obtained by introducing into a flat-bottomed matrass, fig. 120, about 4 ounces of mercury, and placing it in a sand bath, heated to the boiling point of the metal. In about a month's time nearly the whole is converted into oxide. Air is freely admitted by the tube, while its length prevents the escape of mercurial vapour, which condenses and falls back into the body of the vessel; the remaining portion of running mercury may be driven off by exposing it in a basin to a heat just below redness.

Properties.

1515. Peroxide of mercury has an acrid metallic taste, and is poisonous; it dissolves very sparingly in water. When heated, it acquires a black colour, but becomes again red on cooling; at a red heat it evolves oxygen, and is reduced to the metallic state. It should be entirely volatilized when placed upon a red-hot iron, for it is sometimes adulterated with red lead.

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* For more particular directions, see Ure's Dictionary, p. 580.

† It is the *Hydrargyri Oxidum cinereum* of the U. S. Pharmacopœia.

Composition.

1516. It is composed, according to Fourcroy and Thenard, of 100 metal and 8 of oxygen. Sir H. Davy, also, finds its oxygen to be exactly double that of the *protoxide*, which, from his experiments, is composed of 190 mercury, and 7,5 oxygen, while the peroxide consists of 190 metal and 15 oxygen. Hence the protoxide is composed of

Mercury	96.22	100
Oxygen	3,78	3,947
	100	103,947

And the peroxide of

Mercury	92,69	100
Oxygen	7,31	7,894
	100	107,894

Mr Donovan finds that 100 parts of mercury take to form black oxide, 4,12 of oxygen; and, to form red oxide, 7,82. But the two last numbers, not being strictly coincident with the law of multiple proportions, one of them must be erroneous. Admitting the red oxide to consist of 7,82, for every 100 grains of mercury, the black must consist of 100 + 3,91. It will, perhaps, be sufficiently near the truth, if we admit, with Dr Wollaston, that, according to the original determination of Fourcroy and Thenard, confirmed by the recent experiments of Sefstrom,[*] the black oxide consists of 100 metal, united with 4 of oxygen, and the red of 100 mercury + 8 oxygen. The latter number agrees, also with the experiments of Guibourt; and the oxygen in the protoxide, though, from his analysis, it appeared to amount to 4½ oxygen upon 100 mercury; may be safely taken at half that in the peroxide. This would make the atom of mercury to weigh 200, for 4 : 100 :: 8 : 200.

Peroxide of mercury, Guibourt finds, is decomposed by long continued exposure to light. It is soluble in water, and communicates to it the property of turning syrup of violets green, and of being precipitated by sulphuretted hydrogen. With ammonia, the peroxide forms an *ammoniuret of mercury*, decomposable by heat. H. 2. 113.

Chlorides.

1517. Mercury unites easily with chlorine, and if heated in that gas, burns with a pale red flame. The product is identical with the salt, called *corrosive sublimate*, which in fact is a chloride of mercury, and is termed *per-chloride* or *bi-chloride* to distinguish it from *calomel*,[†] another compound of the same elements in different proportions.

Protochloride

1518. *Protochloride of Mercury.*—This compound, commonly termed *calomel*, is first mentioned by Crollius, early in the seventeenth century. The first directions for its preparation are given by Beguin, in the *Tyrocinium Chemicum*, published in 1608. He calls it *draco mitigatus*. Several other fanciful names have been applied to it, such as *aquila mitigata*, *manna metallorum*, *panchymagogum minerale*, *sublimatum dulce*, *mercurius dulcis*, *&c.*

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[*] Ann. of Philos. N. S. ii. 126.

[†] In the *U. S. Pharmacopœia* they are termed *submuriate of mercury* and *oxymuriate of mercury*.

Method of preparing calomel.

The most useful mode of preparing calomel consists in triturating two parts of corrosive sublimate with one of mercury, until the globules disappear, and the whole assumes the appearance of an homogeneous grey powder, which is introduced into a matrass, placed in a sand heat, and gradually raised to redness. The calomel sublimes, mixed with a little corrosive sublimate, the greater part of which, however, being more volatile than the calomel, rises higher in the matrass; that which adheres to the calomel may be separated, by reducing the whole to a fine powder, and washing in large quantities of hot distilled water. Pure calomel, in the form of a yellowish white insipid powder, remains.

It was formerly the custom to submit calomel to very numerous sublimations, under the idea of rendering it *mild;* but these often tended to the production of corrosive sublimate; and the calomel of the first sublimation, especially if a little excess of mercury be found in it, is often more pure than that afforded by subsequent operations.

1519. The following are the directions given in the last *London Pharmacopœia:*

"Take of oxymuriate of mercury, 1 lb.
——— purified mercury, *by weight*, 9 oz.

Rub them together, until the metallic globules disappear; then sublime: take out the sublimed mass, reduce it to powder, and sublime it in the same manner twice more successively. Lastly, bring it to the state of a very fine powder; throw this into a large vessel, full of water; then stir it, and, after a short interval, pour the supernatant turbid solution into another vessel, and set it by, that the powder may subside. Lastly, having poured away the water, dry the powder."[*]

1520. It will be observed, that in these processes the operation consists in reducing the perchloride to the state of protochloride by the addition of mercury. Various modes have, however, been adopted for the direct formation of calomel: two of these may here be noticed, of which the first is in the humid way, as devised by Scheele and Chenevix. They are given below.[†]

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[*] Powell's *Translation of the London Pharmacopœia*, London, 1815. p. 144 and 99. See also U. S. *Pharmacopœia*. 141.

[†] Form a nitrate of mercury, by dissolving as much mercury as possible in hot nitric acid; then dissolve in boiling water a quantity of common salt, equal to half the weight of the mercury used, and render the solution sensibly sour by muriatic acid, and pour the hot nitrate of mercury into it. Wash and dry the precipitate.

If this process be carefully performed, and the precipitate thoroughly edulcorated, the calomel is sufficiently pure.

The second process, however, or that by which calomel is directly formed in the dry way, appears, on the whole, the least exceptionable for the production of this very important article of pharmacy;

Characters. 1521. Protochloride of mercury is usually seen in the form of a white mass, of a crystalline texture, and when very slowly sublimed, it often presents regular four-sided prisms, perfectly transparent and colourless. Its specific gravity is 7,2. It is tasteless and very nearly insoluble in water. It can scarcely be called poisonous, since in considerable doses it only proves purgative. By exposure to light it becomes brown upon its surface. If scratched, it gives a yellow streak, which is very characteristic, and does not belong to the perchloride. When very finely levigated it becomes of a buff colour.

It consists of 1 proportional of mercury 200 + 1 proportional of chlorine 36, and its representative number is 236.

Or, Mercury	85	100	568,2
Chlorine	15	17, 6	100.*
	100.		

1522. When a very small quantity of calomel (about 10 grains) is well triturated with a little water, and then with a considerable quantity of liquid potassa, poured on it at once, an intensely black precipitate is obtained, which, when dried at a gentle heat, and rubbed in a mortar, affords about one-fourth its weight of revived mercury. The remainder is the protoxide already described. H. 2. 115.

Perchloride, or Corrosive sublimate. 1523. *Perchloride of Mercury—Bichloride*, or *corrosive sublimate*, may be obtained by a variety of processes.

When mercury is heated in chlorine, it burns with a pale flame; the gas is absorbed, and a white volatile substance rises, which is the perchloride.

It may also be obtained by dissolving peroxide of mercury in muriatic acid, evaporating to dryness, re-dissolving in water, and crystallizing.

Theory of the process. 1524. The ordinary process for making corrosive sublimate consists in exposing a mixture of chloride of sodium (common salt) and phosphate of mercury, to heat in a flask, or other proper subliming vessel; a mutual decomposition ensues. The chlorine of the common salt unites to the mercury of the sulphate, and forms bi-chloride of mercury. The oxygen of the oxide of mercury converts the sodium of the salt into soda, which, with the sulphuric acid, produces sulphate of

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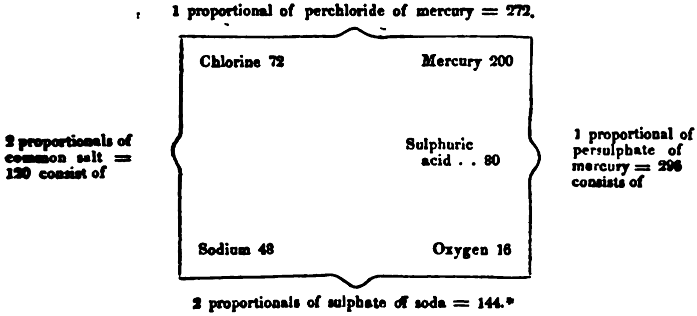
it is the method followed at Apothecaries' Hall, sanction having been obtained for its adoption from the College of Physicians.

50 lbs of mercury are boiled with 70 lbs of sulphuric acid, to dryness, in a cast-iron vessel: 62 lbs of the dry salt are triturated with 40 1-2 lbs of mercury, until the globules disappear, and 34 lbs of common salt are then added. This mixture is submitted to heat in earthen vessels, and from 95 to 100 lbs of calomel are the result. It is to be washed in large quantities of distilled water, after having been ground to a fine and impalpable powder.

[*] *Native Chloride of Mercury* or *mercurial horn ore*, has been found in Germany, France, and Spain, usually crystallized, and sometimes incrusting and massive.

soda. This decomposition is exhibited by the following diagram:


1 proportional of perchloride of mercury = 272.
Chlorine 72
Mercury 200
2 proportionals of common salt = 120 consist of
Sulphuric acid . . 80
1 proportional of persulphate of mercury = 296 consists of
Sodium 48
Oxygen 16
2 proportionals of sulphate of soda = 144.[*]

Composition.

1525. By the quantity of chlorine absorbed by a given weight of mercury, we learn that the perchloride of mercury consists of 1 proportional of mercury = 200 + 2 proportionals of chlorine = 72, consequently its representative number is 272.

Characters.

1526. Perchloride of mercury is usually seen in the form of a perfectly white semi-transparent mass, exhibiting the appearance of imperfect crystallization. It is sometimes procured in quadrangular prisms. Its taste is acrid and nauseous, leaving a peculiar metallic and astringent flavour upon the tongue. It dissolves in 20 parts of water at 60°, and in about half its weight at 212°. It is more soluble in alcohol than in water. When heated, it readily sublimes in the form of a dense white vapour, strongly affecting the nose and mouth. It dissolves without decomposition in muriatic, nitric, and sulphuric acids: the alkalies and several of the metals decompose it. It produces, with muriate of ammonia, a very soluble compound; hence a solution of sal-ammoniac is used with advantage in washing calomel to free it from corrosive sublimate.

1527. Protochloride and perchloride of mercury are decomposed by potassa, soda, and lime; the former affords *black*, (*hydrargyri oxidum cinereum* of the *London*, and *U. S. Pharmacopœia*,) the latter *red*, oxide of mercury; and the chlorides of potassium, sodium, and calcium, are produced.

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[*] The following are the official directions of the *London* (*and U. S.*) *Pharmacopeia*, for the preparation of corrosive sublimate, there termed *oxymuriate of mercury*.

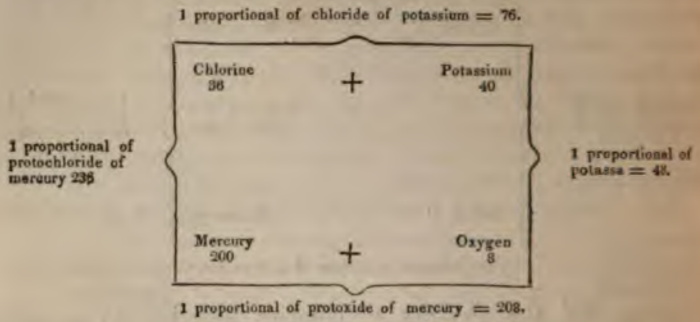
"Take of purified mercury, *by weight*, 2 lbs.
——— sulphuric acid, *by weight*, 30 oz.
——— dried muriate of soda, 4 lbs.

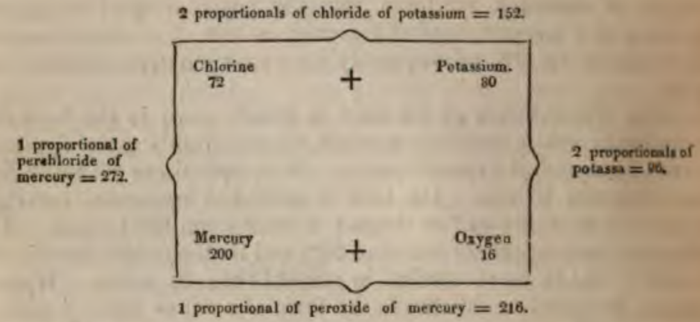
Boil the mercury with the sulphuric acid in a glass vessel, until the sulphate of mercury is left dry. Rub this when it is cold with the muriate of soda in an earthen-ware mortar; then sublime it in a glass cucurbit, increasing the heat gradually."—Powell's *Translation*.

The quantity of common salt employed in this process is obviously too large; in practice, however, we find that more than the real quantity decomposed, and shown in the above table, is required.

The following is the process employed at Apothecaries' Hall for the formation of corrosive sublimate: 50 lbs of mercury are boiled to dryness with 70 lbs of sulphuric acid. 73 lbs of persulphate of mercury are thus formed, which being perfectly mixed with 120 lbs of common salt and sublimed, yield from 63 to 65 lbs of corrosive sublimate. B.

The following diagrams shew the interchange of elements that takes place in the case of adding a solution of potassa to protochloride and perchloride of mercury.


1 proportional of chloride of potassium = 76.
Chlorine 36
+
Potassium 40
1 proportional of protochloride of mercury 236
1 proportional of potassa = 48.
Mercury 200
+
Oxygen 8
1 proportional of protoxide of mercury = 208.


2 proportionals of chloride of potassium = 152.
Chlorine 72
+
Potassium. 80
1 proportional of perchloride of mercury = 272.
2 proportionals of potassa = 96.
Mercury 200
+
Oxygen 16
1 proportional of peroxide of mercury = 216.

1528. When solution of ammonia is poured upon calomel, protoxide of mercury, and muriate of ammonia, are the results; but ammonia, added to a solution of corrosive sublimate, occasions a white precipitate of a *triple muriate of ammonia and mercury.*[*]

1529. Muriate of ammonia renders corrosive sublimate more soluble in water, one part rendering five parts soluble in rather less than five of water. By evaporation a triple salt is obtained, formerly called *sal alembroth.* The addition of potassa or soda throws down the above-mentioned white precipitate. Hence its use in washing calomel.

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[*] A compound of this kind has long been used in pharmacy, under the name of *calx hydrargyri alba* or *white precipitate.* The London and U. S. Pharmacopœia direct the following process for its formation:

Take of oxymuriate mercury 1-2 lb.
——- muriate of ammonia 4 oz.
——- solution of subcarbonate of potassa 1-2 pint.
——- distilled water 4 pints.

First dissolve the muriate of ammonia, then the oxymuriate of mercury, in the distilled water, and add thereto the solution of subcarbonate of potassa. Wash the precipitated powder until it becomes tasteless: then dry it.

In the U. S. P. it is termed *Hydrargyri Submurias Ammoniatus.*

1530. *Chlorate of Mercury.*—Chloric acid dissolves both the oxides of mercury; the *protochlorate* has the appearance of a yellowish granular powder, sparingly soluble in hot water, and of a mercurial taste. The *perchlorate* forms white acicular crystals, having the acrid flavour of the perchloride.* Chlorate.

1531. *Mercury and Iodine* unite in two proportions. These compounds may be procured either by gently heating mercury with iodine, or by adding hydriodic acid to solutions of mercury. The *protiodide* is yellow, and the *periodide* red. They respectively consist of 1 proportional of mercury + 1 of iodine and 1 + 2. They are both insoluble in water.† Iodide.

1532. *Mercury and Nitric Acid.*—Nitric acid is rapidly decomposed by mercury; nitrous acid, and nitric oxide gases are evolved, and either a protonitrate or a pernitrate of mercury is obtained, according to the mode in which the solution is performed. Nitrates.

1533. *Protonitrate of Mercury* is best obtained by dissolving the metal in a cold and dilute acid, consisting of one part of acid and three of water; the metal should be added in small successive portions until the acid ceases to act upon it, and care should be taken to keep the whole cold. This solution deposits transparent crystals which appear to be modified octoëdra, and which consist of the protoxide of mercury combined with nitric acid. They are soluble without decomposition in cold water, and the solution affords black precipitates of protoxide upon the addition of the alkalies.

1534. *Pernitrate of Mercury.*—When mercury is dissolved in hot and concentrated nitric acid, it becomes peroxidized, and furnishes prismatic crystals of the pernitrate. Their solution furnishes yellow or red precipitates of the peroxide of mercury, upon the addition of potassa or soda, and ammonia forms a white precipitate which is a *triple nitrate of mercury and ammonia.*

When the precautions in forming the nitrates above described are not attended to, the solution usually contains a mixture of the two nitrates, and furnishes a precipitate with the alkalies, composed of both oxides. The pernitrate is most certainly formed by dissolving the red oxide in nitric acid.

1535. When hot water is poured upon pernitrate of mercury, a yellow insoluble powder separates from it, which is a *subpernitrate,* the *nitrous turpeth* of old writers; and a *super-pernitrate* remains in solution. It seems probable that the protonitrate is also capable of affording a sub and super nitrate, but all these compounds have hitherto been but imperfectly investigated, and new researches are wanting to establish their nature and composition.

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* Vauquelin, *Annales de Chimie,* xci.

† *Iodate of Mercury.*—Iodate of potassa occasions a precipitate in protonitrate of mercury, but not a the pernitrate.

If the protonitrate and pernitrate be composed of one proportional of each of the oxides with one of acid and with two of acid, the following will be their component parts.

208	protoxide	216	peroxide
54	nitric acid	108	nitric acid
262	protonitrate of M.	324	pernitrate of M.

The subpernitrate has been analyzed by M. M. Braamcamp and Oliva,* and they report its composition at

12	acid
88	peroxide
100	

If its composition in theory be admitted as 2 proportionals of peroxide = 432 + 1 proportional of nitric acid = 54, these numbers are not much at variance with the above experimental result, thus, 88 : 12 : : 432 : 58.

Decomposed by heat. 1536. When these nitrates of mercury are exposed to heat gradually raised to dull redness, nitric acid is given off; and a brilliant red substance remains, consisting of peroxide of mercury with a small portion of adhering nitrate. This is used in pharmacy as an escharotic and is called in the U. S. Pharmacopœia *hydrargri nitrico-oxidum*.†

Fulminating mercury. 1537. *Fulminating Mercury.*—Mercury is the basis of a *fulminating compound* discovered by the late Mr E. Howard. To prepare this powder, 100 grains (or a greater proportional quantity, not exceeding 500,) are to be dissolved, with heat, in a measured ounce and half of nitric acid. The solution being poured cold upon two measured ounces of alcohol, previously introduced into a convenient glass vessel, a moderate heat is to be applied till effervescence is excited. A white fume then begins to undulate on the surface of the liquor, and the powder will be gradually precipitated on the cessation of action and reaction. The precipitate is to be immediately collected on a filter, well washed with distilled water, and cautiously dried in a heat not exceeding that of a water-bath. The immediate washing of the powder is material, because it is liable to the reaction of the nitric acid; and while any of that acid adheres to it, it is very subject to be decomposed by the action of light. From 100 grains of mercury, about 120 or 130 of the powder are obtained.‡ This powder has the property of detonating loudly in a gentle heat, or by light friction. Hence it has been proposed as a means of firing ordnance. But an accident described by Professor Silliman, as having happened in his laboratory, shows that this fulminating compound explodes from such triling causes, as not to be kept without danger, even when secured from friction or heat.* H. 2. 117. It is regarded as a compound of mercury and cyanic acid. See (1589.)

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* Thomson, Vol. ii. p. 475; A edit.

† In the manufacture of this compound at Apothecaries' Hall, (Lond.) 100 lbs of mercury are boiled with 48 lbs of nitric acid (sp. gr. 1,48) and by proper evaporation and application of a dull red heat 112 lbs of the *hydrargyri nitrico-oxidum* are obtained. B.

‡ See Phil. Trans. 1800, p 214.

Sulphuret.

1538. *Mercury and Sulphur.*—When one part of mercury is triturated for some time with three of sulphur, a black tasteless compound is obtained, which was called in old pharmacy *Æthiops Mineral;* it is the *hydrargyri sulphuretum nigrum* of the U. S. Pharmacopœia.†

The same substance is more readily formed by pouring mercury into melted sulphur, the substances quickly combine, with such a rise of temperature as often produces inflammation.

1539. There is some difficulty in ascertaining how far these are definite compounds; when, however, sulphuretted hydrogen is passed through a dilute solution of nitrate of mercury, a black powder is thrown down, which appears to be a true sulphuret, and which, according to Guibourt,‡ consists of 100 mercury + 8,2 sulphur, numbers which nearly correspond to

1 proportional mercury = 200
1 ———— sulphur = 16

Sulphuret of mercury = 216

1540. When the black sulphuret is heated red hot in a flask, a portion of mercury evaporates, and a sublimate of a steel grey colour is obtained, which, when reduced to a fine powder, assumes a brilliant red colour, and is called *vermillion* or *cinnabar.* It is, in fact, a *bisulphuret of mercury,* and consists of

1 proportional of mercury = 200
2 ———— sulphur = 32

Bisulphuret of mercury = 232

Manufacture of cinnabar.

1541. In the manufacture of cinnabar 8 parts of mercury are mixed in an iron pot with one of sulphur, and made to combine by a moderate heat, and constant stirring: this compound is then transferred to a glass subliming vessel, (on a small scale a Florence flask answers perfectly,) and heated to redness in a sand bath; a quantity of mercury and of sulphur evaporate, and a sublimate forms which is removed, and rubbed or levigated into a very fine powder.

1542. Cinnabar is not altered by exposure to air or moisture; when heated to dull redness in an open vessel, the sulphur forms sulphurous acid, and the mercury escapes in vapour. It is decomposed by distillation with fixed alkalies, lime, and baryta, and by several of the metals. When adulterated with red lead it is not entirely volatile.

1543. Cinnabar may be made in the humid way by long trituration of mercury and sulphur in solution of potassa.§

Native cinnabar.

1544. *Native Cinnabar* is the principal ore of mercury: it occurs massive and crystallized of various colours, sometimes appearing steel grey, at others bright red. Native mercury, and native amalgam of silver sometimes accompany it.*

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* Amer. Jour. i. 168.

† It is no longer retained in the *London Pharmacopœia*

‡ Annales de Chimie, et Phys. Tom. i.

§ Nicholson's *Journal.* iv. to ii.

Sulphates. 1545. *Mercury and Sulphuric Acid.*—When mercury is boiled in its weight of sulphuric acid, sulphurous acid gas is evolved, a part of the metal is oxydized and dissolved and a white deliquescent mass is obtained, which, washed with cold water, affords a very difficultly soluble white salt, which is a *proto-sulphate of mercury*. It requires 500 parts of water for its solution and crystallizes in prisms. According to Fourcroy† it consists of

12 sulphuric acid
83 protoxide of mercury
5 water.

According to theory, it should consist of one proportional of sulphuric acid + 1 of protoxide, or

40 sulphuric acid
208 protoxide of mercury
———
248 sulphate of mercury.

The alkalies precipitate black oxide of mercury from this salt.

Persulphates. 1546. If three parts of sulphuric acid be boiled to dryness with one of mercury, a white mass of *persulphate of mercury* is obtained; it is more soluble than the sulphate and crystallizes in prisms. According to Braamcamp and Oliva, it is composed of

31,8 acid
63,8 peroxide
4,4 water
———
100,0

It should consist, according to theory, of 1 proportional of peroxide + 2 proportionals of acid.

1547. When hot water is poured upon persulphate of mercury, a yellow insoluble *subpersulphate* is formed, formerly called *Turpeth mineral.*‡ It appears to consist of 1 proportional of peroxide + 1 of acid, or

216 peroxide of mercury
40 sulphuric acid
———
256 subpersulphate of mercury.

A *bipersulphate* remains in solution.

1548. The solutions of persulphate of mercury furnish red precipitates with the fixed alkalies, and white with ammonia, the latter being a triple *sulphate of ammonia and mercury.*

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* *Hyposulphite of Mercury* appears not to exist: when a solution of a hyposulphite is poured into a very dilute solution of protonitrate of mercury it occasions a black precipitate.

† Annales de Chimie, x.

‡ *Hydrargyri subsulphas flavus* of the U. S. Pharmacopœia.

1549. Sulphuretted hydrogen produces a black precipitate in solutions of mercury when added in excess, and which appears to be a sulphuret of mercury.[*]

1550. *Mercury and Phosphoric Acid.*—When phosphate of soda is added either to nitrate or pernitrate of mercury, a white precipitate is formed. There is probably a *protophosphate* and a *perphosphate*. The latter is soluble in excess of acid.

1551. *Mercury and Carbonic Acid.*—Alkaline carbonates produce buff-coloured precipitates in solutions of both oxides of mercury. These are probably the *protocarbonate* and the *percarbonate*. Carbonates.

1552. *Mercury and Cyanogen.*—Cyanide of mercury may be prepared by boiling in a matrass eight parts of water, two of finely powdered prussian blue, and one of peroxide of mercury. When the liquid assumes a yellow colour, it is to be filtered, and the cyanide of mercury is deposited in a crystallized form on cooling.[†] By repeated evaporation and cooling, all the cyanide that is capable of crystallizing will be separated, mingled however with some oxide of iron. To purify it, Proust recommends that it be re-dissolved; boiled with an excess of oxide of mercury; and again filtered. The liquid retains an excess of the oxide, which may be saturated by adding hydrocyanic acid, for the oxygen instantly passes to the hydrogen of the acid, and the cyanogen to the mercury. The cyanide may now be crystallized again; and, if intended for the preparation of cyanogen, it must be thoroughly dried, avoiding however more heat than is absolutely necessary. H. 2. 116. Cyanide.

1553. Cyanide of mercury is decomposed by heat, as in the process for obtaining cyanogen; and if distilled with muriatic acid, hydrocyanic acid and chloride of mercury are formed. It also is decomposed by hydriodic acid and by sulphuretted hydrogen, an iodide and a sulphuret of mercury, and hydrocyanic acid, being formed. The alkalies do not act upon this cyanide. Decomposed by heat.

1554. Cyanide of mercury is also formed by boiling peroxide of mercury in solution of ferrocyanate of potassa; a portion of mercury and of peroxide of iron are at the same time deposited, whence it appears that the oxygen of the mercurial oxide is partly transferred to the iron, and partly to the hydrogen of the ferrocyanic acid.

1555. Cyanide of mercury boiled in water with peroxide of mercury produces a compound which forms small granular crystals consisting of cyanide and oxide of mercury; hence in making the cyanide by the above process, excess of mercurial oxide should be avoided.[‡]

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[*] *Phosphuret of Mercury* may be formed by heating phosphorus with oxide of mercury. It is a sectile solid of a bluish black colour.

[†] According to Gay-Lussac the crystals are composed of 80 mercury + 20 cyanogen. They probably contain 1 proportional of mercury and 2 of cyanogen. B.

[‡] *Borate of Mercury*, obtained by adding borate of soda to nitrate of mercury, is a yellow insoluble powder.

Arseniates.

1556. *Arseniates of Mercury.*—Arsenic acid occasions a pale yellow precipitate in solution of protonitrate of mercury, and a yellowish white precipitate in solution of the pernitrate. Arsenious acid produces white precipitates in both solutions.

1557. Molybdic acid occasions a white precipitate in solution of nitrate of mercury.

Chromate.

1558. *Chromate of Mercury.*—Chromate of potassa throws down an orange-coloured precipitate from the solutions of nitrate and pernitrate of mercury.

Characters of the salts of mercury.

1559. The soluble salts of mercury furnish whitish precipitates with ferrocyanate of potassa, and black with sulphuretted hydrogen. A plate of copper, immersed into their solutions, occasions the separation of metallic mercury.

The insoluble mercurial salts are mostly entirely volatilized at a red heat; if distilled with charcoal, they afford metallic mercury.

Amalgams.

1560. Mercury combines with most of the other metals, and forms a class of compounds which have been called *amalgams*. These are generally brittle or soft. One part of potassium with 70 of mercury produce a hard brittle compound. If mercury be added to the liquid alloy of potassium and sodium (928), an instant solidification ensues, and heat enough to inflame the latter metal is evolved. The use of an amalgam of zinc and mercury has already been adverted to for the excitation of electrical machines. The amalgams of gold and silver are employed in gilding and plating.

An amalgam of 2 parts of mercury, 1 of bismuth, and 1 of lead, is fluid, and when kept for some time, deposits cubic crystals of bismuth.

Amalgam of copper.

Amalgam of copper may be made as follows: To a hot solution of sulphate of copper, add a little muriatic acid, and a few sticks of zinc, and boil the mixture for about a minute: by this means the copper will be precipitated in a metallic state, and in a finely divided spongy form: take out the zinc, pour off the liquor, wash the copper with hot water, and pour upon it a little dilute nitrate of mercury, which will instantly cover every particle of copper with a coating of mercury: then add mercury to the amount of two or three times the weight of the copper, and a slight trituration will combine them so far that the completion of the process may be effected by heating the mixture for a few minutes in a crucible.*

Oxidation of metals promoted by mercury.

1561. By combination with mercury, metals that are not easily oxidized, acquire a facility of entering into union with oxygen. Thus gold and silver, when combined with mercury, are oxidized by ignition in contact with air. This fact furnishes a striking illustration of the effect of overcoming the aggregative affinity of bodies in promoting chemical union. H.

1562. When mercury is negatively electrized in a solution of ammonia, or when an amalgam of potassium and mercury is placed upon moistened muriate of ammonia, the metal increases in volume, and becomes of the consistency of butter, an appearance which has sometimes been called the *metallization of ammonia.* The compound appears only to contain ammonia and mercury, though its real nature has not been satisfactorily ascertained. It has suggested some hypotheses concerning the nature of ammonia and the metals, which are not worth recording.

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* Aikin's *Dictionary*, Art. *Mercury*, p. 92.

SECTION XXX. *Osmium.*

Process for obtaining osmium.

1563. OSMIUM, and the metals described in the three following sections are contained in the ore of platinum. This ore is digested in nitro-muriatic acid, by which the greater portion is dissolved, and there remains a black powder, which, when fused with potassa and washed, furnishes a yellow alkaline solution of oxide of osmium. Saturate the alkali with sulphuric acid, pour the mixture into a retort, and distil. A colourless solution of the *oxide of osmium* passes into the receiver; it has a sweetish taste and a very peculiar smell, somewhat like that of new bread. When mercury is shaken with this solution it becomes an amalgam, which is decomposed by distillation and pure osmium remains.

1564. Osmium has a dark grey colour, and is not volatile when heated in close vessels; but heated in the air it absorbs oxygen, and forms a volatile oxide. It has not been fused.

Characters.

1565. The leading characters of osmium are its insolubility in the acids, its ready solubility in potassa, the facility with which it is oxidized, the singular smell of its oxide, its great volatility, and the purple or blue colour produced in its solution by tincture of galls. The other compounds have scarcely been examined.

1566. M. Laugier having observed that nitro-muriatic acid, which has been employed to dissolve platinum, emits a strong odour, of osmium, distilled the liquor and saturated the product with quicklime; after which by again distilling the liquid, he obtained a quantity of osmium sufficient to repay the trouble of the process.* H.

SECTION XXXI. *Iridium.*

How obtained.

1567. THE black powder mentioned in the last section contains iridium, which resists the action of potassa, and consequently remains after the separation of osmium. A solution of its oxide may be procured by digesting it in muriatic acid, which first becomes blue, then olive-green, and lastly, red.

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* Ann. de Chim. 89. p. 191.

By alternate treatment with potassa and muriatic acid, the whole of the black powder will be dissolved. By evaporating the muriatic solution to dryness, dissolving the dry mass in water, and evaporating a second time, octoëdral crystals of muriate of iridium are obtained.

Method of obtaining from the muriate.

1568. Iridium is obtained by immersing a plate of zinc into a solution of the muriate, or by violently heating the octoëdral crystals. It is of a whitish colour, and according to Mr Children, who succeeded in fusing it by means of his large voltaic apparatus, its specific gravity is above 18. Its most marked character is extremely difficult solubility in the acids.

1569. In crude platinum Dr Wollaston discovered some flat white grains which resisted the action of the acids, and which he ascertained to consist of *a native alloy of osmium and iridium.*

Discovery.

1570. Osmium and iridium were discovered by Mr Tennant in 1803. The name of the former is derived from the peculiar smell of its oxide; that of the latter, from the variety of colours exhibited by its solution.*

Section XXXII. *Rhodium.*

Discovery.

1571. Rhodium and Palladium were discovered by Dr Wollaston in 1803.† These, like the two last described metals, exist in the ore of platinum, from which rhodium may be obtained by the following process: Digest crude platinum in a small quantity of nitro-muriatic acid, filter the saturated solution, and pour it into a solution of sal ammoniac, by which the greater proportion of the platinum is precipitated. Decant the clear liquor and immerse a plate of zinc, which becomes coated with a black powder. Separate this and digest it in dilute nitric acid, by which a little copper and lead are taken up. Then wash and digest in dilute nitro-muriatic acid, to which add some common salt, evaporate to dryness, and wash the dry mass repeatedly with alcohol. A deep red substance remains, which, when dissolved in water, furnishes a black precipitate upon the immersion of a plate of zinc. This strongly heated with borax, assumes a white metallic lustre, and is rhodium.

How obtained.

Properties.

1572. Rhodium is very difficult of fusion; its specific gravity is 10,6. When an alloy of lead and rhodium is digested in nitro-muriatic acid, it is dissolved, and by evaporation a red compound is obtained, from which muriate of rhodium may be separated by water, or more perfectly by alcohol. The rose-colour of this compound suggested the name which has been applied to the metal.

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* Phil. Trans. 1804.

† Palladium was also discovered by Mr Cloud in a native alloy of gold with that metal.

Oxides.

1573. Berzelius has described three oxides of this metal, composed as follows:

	Metal.		Oxygen.
Protoxide	100	+	6,71
Deutoxide	100	+	13,42
Peroxide	100	+	20,13

1574. Rhodium forms malleable *alloys* with the malleable metals, several of which have been examined by Dr Wollaston.*

Alloys.

With steel, rhodium forms an alloy, which probably would be very useful in the arts, were it not for the scarcity of the latter metal. 1 to 2 per cent. of rhodium gives steel great hardness, and yet there is sufficient tenacity to prevent cracking either in forging or hammering.†

SECTION XXXIII. *Palladium.*

How obtained.

1575. PALLADIUM is most easily obtained by the following process.‡ Digest the ore of platinum in nitro-muriatic acid, neutralize the redundant acid by soda, throw down the platinum by muriate of ammonia, and filter. To the filtered liquor add a solution of cyanide of mercury (1552); a yellow flocculent precipitate is soon deposited which yields palladium on exposure to heat.§

Properties.

1576. Palladium is of a dull white colour, malleable and ductile. Its specific gravity is about 11. It is hard. It fuses at a temperature above that required for the fusion of gold.

1577. Dr Wollaston has ascertained the existence of *native palladium* in the ore of platinum. It is in small fibrous grains.

Action of acids and alkalies.

1578. Muriatic acid boiled upon palladium acquires a fine red colour. Sulphuric acid becomes blue. Nitric acid readily dissolves it; but its best solvent is the nitro-muriatic, which forms a fine red solution. The alkalies throw down an orange-coloured precipitate from these solutions, sparingly soluble in the alkalies. Ferrocyanate of potassa gives an olive green precipitate; and sulphuretted hydrogen, one of a dark brown colour.

Oxides.

1579. Berzelius has shown that 100 parts of palladium unite with 14,209 parts of oxygen. Hence the oxide consists of

Palladium	87,56
Oxygen	12,44
	100.

Sulphuret.

Palladium readily combines with sulphur. The compound is whiter than the separate metal, and is very brittle. It has been investigated by Berzelius, and shown to be composed as follows:

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* Phil. Trans. 1804. Thomson's *System*, Vols. i. and ii.

† Quarterly Journal, ix. 328.

‡ Wollaston, *Phil Trans.* 1805.

§ See also a process by Vauquelin in *Ann. Philos.* Vols. iv. and vii.

Palladium	78,03	100,
Sulphur	21,97	28,15
	100,	128,15

Equivalent number.

1580. The equivalent number for the metal, deducible both from the oxide and sulphuret is 56,2. We may therefore denote the weight of its atom by 56, that of the oxide by 64; and of the sulphuret by 72. H. 2. 149.

SECTION XXXIV. *Silver.*

Native silver.

1581. SILVER is found native, and in a variety of combinations. *Native Silver* has the general characters of the pure metal. It occurs in masses; arborescent; capillary; and, sometimes, crystallized in cubes and octoëdra. It is seldom pure, but contains small portions of other metals, which affect its colour and ductility. It is chiefly found in primitive countries. In Peru and Mexico are the richest known mines of native silver.

Methods of obtaining pure silver.

1582. To obtain silver in a state of purity, Mr Donovan recommends, that 240 grains of standard silver be dissolved in as much pure nitric acid of specific gravity about 1,2, as will be barely necessary for solution. This is to be filtered, and distilled water allowed to run through the filter, until the fluids amount to two ounce measures. A bright plate of copper weighing upwards of 64 grains, is to be immersed and frequently agitated in it. When the silver has entirely precipitated, which will very soon happen, the clear supernatant liquor is to be poured off, and the precipitate to be well washed with pure water. The silver is then to be boiled for a few minutes in liquid ammonia. It is then to be well washed with water and dried on a filter; after which, if required, it may be melted in a crucible.*

It may also be procured by adding to the above solution of standard silver a solution of common salt; collect, wash, and dry the precipitate, and fuse it with its weight of carbonate of potassa. A button of the pure metal is thus obtained.

Characters.

1583. Silver has a pure white colour, and considerable brilliancy. Its specific gravity is 10,5. It is so malleable and ductile, that it may be extended into leaves not exceeding a ten-thousandth of an inch in thickness, and drawn into wire finer than a human hair.

1584. Silver melts at a bright red heat, and when in fusion appears extremely brilliant. It resists the action of air at high

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* Phil. Mag. xlvii. 206.

Tarnish. Effect of water. — of heat.

temperatures for a long time, and does not oxidize; the *tarnish* of silver is occasioned by sulphureous vapours; it takes place very slowly upon the pure metal, but more rapidly upon the alloy with copper used for plate, and was found by Proust to consist of sulphuret of silver. Pure water has no effect upon the metal; but if the water contain vegetable or animal matter, it often slightly blackens its surface in consequence of the presence of sulphur. If an electric explosion be passed through fine silver wire, it burns into a black powder, which is an oxide of silver. In the Voltaic circle it burns with a fine green light, and throws off abundant fumes of oxide. Exposed to an intense white heat, it boils and evaporates. If suddenly cooled, it crystallizes during congelation, often shooting out like a cauliflower, and throwing small particles of the metal out of the crucible.

1585. Silver is not unfrequently obtained in considerable quantities from argentiferous sulphuret of lead, which is reduced in the usual way and then *cupelled;* the oxide of lead thus procured is afterwards reduced by charcoal.

Amalgamation.

Some of the silver ores, especially the sulphurets, are reduced by amalgamation. These ores, when washed and ground, are mixed with a portion of common salt and roasted; it is then powdered and mixed by agitation with mercury, and the amalgam thus formed is distilled.

Eliquation.

The old process of *eliquation* is now scarcely used: it consisted in fusing alloys of copper and silver with lead; this triple alloy was cast into round masses which were set in a proper furnace upon an inclined plane of iron with a small channel grooved out, and heated red-hot, during which the lead melted out, and in consequence of its attraction for silver, carried that metal with it, the copper being left behind in a reddish black spongy mass.*

1586. From some curious facts which are stated by Mr Lucas,† it appears that silver, when melted, and exposed to a current of air or of oxygen gas, forms a temporary union with oxygen, which is again given off in the state of gas, when the metal cools spontaneously, or is poured into cold water. This property, it has been shown by Chevillot‡ belongs only to pure silver, and not to silver alloyed even with a very small proportion of copper. H. 2. 121.

Oxide.

1587. *Oxide of silver* may be obtained by adding lime-water to the solution of nitrate of silver, and washing the precipitate. It is of a dark olive colour, tasteless, insoluble in water, and when gently heated, is reduced to the metallic state.

The composition of oxide of silver has been very variously given, probably from the difficulty of obtaining it of similar purity. According to Sir H. Davy 100 parts of silver unite with 7,3 oxygen, or according to Dr Wollaston's scale 7,4. A larger proportion of oxygen was formerly assigned by Berzelius; but he has recently given the following statement.

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* Aikin's *Dictionary*, Art. Silver.

† Manchester Society's Memoirs, N. S. Vol. iii.

‡ Ann. de Chim. et Phys. xiii. 299.

Composition.

Silver	93,12	100,
Oxygen	6,88	7,3986
	100,	107,3986*

Taking the proportion of oxygen which combines with 100 parts of silver at 7,3 the equivalent number for silver will be 110. No other oxide of silver has been actually ascertained to exist; though from the experiments of Mr Faraday, there seems reason to believe that the pellicle, which forms spontaneously on an ammoniacal solution of oxide of silver, exposed to the air, is a protoxide of that metal in which the oxygen is to the silver as 7,5 to 157,4 † H. Dr Thomson admits it to be a distinct oxide (*sub-oxide*) and considers it as constituted of 1½ atom of silver + 1 atom of oxygen.‡

Fulminating silver.

1588. *Fulminating Silver.*—Precipitate nitrate of silver by lime-water, and thoroughly edulcorate and dry the precipitate. Let this be afterward put into a vessel of the purest liquid ammonia, in which it may remain for ten or twelve hours. It will then assume the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air. This is the celebrated compound termed *fulminating silver,* which detonates with the gentlest heat, and even with the slightest friction. It may be formed, also, by boiling any precipitated oxide of silver, for a few moments, in a mixed solution of potassa and ammonia. The protoxide, however, described by Mr Faraday does not afford it. When once prepared, no attempt must be made to enclose it in a bottle, and it must be left undisturbed in the vessel in which it was dried. Great caution is necessary in the preparation of this substance for in making experiments on it, several fatal accidents have been produced by indiscretion in its use. It even explodes, when moist, on the gentlest friction.§ H. 2. 126.

Detonating silver.

1589. Another detonating compound of silver, formed by a process similar to that employed in making the fulminating mercury of Mr Howard, has been described by Descotils.|| It is prepared by adding alcohol, to a heated solution of silver, in nitric acid, while the solution is yet going on. Considerable effervescence arises; the liquor presently becomes turbid; and a heavy, white, crystalline powder falls down. This, when washed and dried, is the *detonating silver.* Heat, a slight blow, or long continued friction, cause it to inflame, with a brisk detonation. Pressure alone is not sufficient unless very powerful. It detonates by the electric spark, and is set on fire with an explosion by concentrated sulphuric acid. Both in the

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* Ann. of Philos. xv. 93.

† Quart. Jour. iv. 270.

‡ First Principles, i. 434.

§ See Count Rumford's papers, Phil. Trans. 179

|| Nicholson's Journal, xviii. 140.

preparation of this substance, and in experiments on its detonation, much caution is necessary; and only very small quantities should be employed. This preparation was originally discovered by Mr E. Howard. In repeating his process Mr Cruickshank dissolved 40 grains of silver in two ounces of strong nitric acid, diluted with an equal weight of water. Then, by heating the solution with two ounces of alcohol, he obtained 60 grains of a white powder, which detonated violently. H. 2. 127.

Fulminic acid.

The detonating salts of silver, mercury, (1536) &c. have been examined by Dr Liebeg. In an able series of experiments he found that these detonating salts contained an acid to which the name *fulminic* was first applied. Subsequent experiments by the same chemist in conjunction with M. Gay-Lussac have shown that this acid is the cyanic, and that it combines with different bases, and thus forms as many detonating compounds. But it cannot be obtained from them in an insulated state.[*]

Chloride.

1590. *Silver and Chlorine.—Chloride of Silver.*—This compound is easily procured by adding a solution of chlorine, of muriatic acid, or of common salt, to a solution of nitrate of silver: it falls in the form of a heavy insoluble tasteless powder, of a white colour, but which, by exposure to light, becomes brown, and ultimately black. When dry chloride of silver is heated to dull redness in a silver crucible it does not lose weight, but fuses; and, on cooling, concretes into a grey semi-transparent substance, which has been called *horn silver*, or *luna cornea*. If slowly cooled, Proust has remarked that it has a tendency to octoëdral crystallization. Heated to a bright red or white heat in an open vessel, it volatilizes in dense white fumes.

1591. If fused with twice its weight of potassa or soda, chloride of silver is decomposed, and a globule of metallic silver is obtained. It is also rapidly decomposed by tin and zinc. Triturated with zinc filings and moistened, the heat produced is so considerable as to fuse the resulting alloy of zinc and silver.[†]

Action of ammonia.

1592. Chloride of silver is very soluble in ammonia, a circumstance by which it is usefully distinguished from some other chlorides, which, like it, are white, and formed by precipitation. We should be cautious in applying heat to the ammoniacal solution, as it sometimes forms a precipitate of fulminating silver. The ammoniacal solution furnishes crystals, which, when exposed to air, or put into water, lose their transparency, ammonia is evolved, and they crumble into chloride of silver. The fused chloride, exposed to ammoniacal gas, absorbs a considerable portion, which is given off by heat. If the dry chloride thus saturated with ammonia, be thrown into chlorine the ammonia spontaneously inflames.[‡] Chloride of silver is soluble in and decomposed by all the liquid hyposulphites.

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[*] See *Ann. de Chim. et Phys.* xxv.—Thenard, *Traité de Chim.* vol. 5, p. 318 edit. 4.—*Boston Journal of Philos.* vol. 3, p. 140.

[†] Faraday, *Quarterly Journal of Science and Arts*, viii. 374

[‡] Faraday, *Quarterly Journal*, v. 75.

Composition. 1593. To know the composition of chloride of silver, 100 grains of the metal may be dissolved in nitric acid and precipitated by a solution of common salt. The precipitate being carefully washed, dried, and fused, the increase of weight on the silver shows the quantity of chlorine which has been gained. Different chemists have given different statements. Wenzel found that 100 of silver gave 131,4 of chloride; Davy, 132,5; Bucholz, Rose, Marcet, and Gay-Lussac, 133,3, and Berzelius, from several experiments, considers 132,75 as the true product.* Taking Sir H. Davy's result, the composition of chloride of silver is

Silver	75,5	100,	307,69
Chlorine	24,5	32,5	100,
	100.		

And the equivalent number for silver, deducible from this analysis, is 110,7, from Berzelius's 109,9. It will perhaps be very near the truth if taken at 110, a number agreeing with that indicated by the composition of the oxide.† H. 2. 122.

Chlorate. 1594. *Chlorate of Silver* is formed by digesting oxide of silver in chloric acid: it forms small rhombic crystals, which, by the action of chlorine, are converted into chloride of silver.

1595. Muriatic acid has no action upon a piece of clean silver, unless boiled with it for a long time, when a slight crust of chloride forms upon it. A beautiful experiment, illustrating the influence of electricity on chemical action, consists in attaching a slip of silver to one of zinc, and putting the double bar into dilute muriatic acid; the silver instantly acquires a crust of chloride in consequence of the negative energy imparted to it by the zinc, the latter metal being rapidly dissolved. Exp.

Iodide. 1596. *Iodide of Silver* is precipitated upon adding hydriodic acid to a solution of nitrate of silver. It is of a greenish yellow colour, insoluble and decomposed when heated with potassa. It is particularly characterized by insolubility in ammonia.

Iodate. 1597. *Iodate of Silver* is precipitated in the form of a white powder by adding iodic acid or iodate of potassa to a solution of nitrate of silver. It is very soluble in ammonia.

Nitrate. 1598. *Nitrate of Silver.*—Nitric acid diluted with three parts of water, readily dissolves silver, with the disengagement of nitric oxide gas. If the acid contain the least portion of muriatic, the solution will be turbid, and deposit a white powder; and if the silver contain copper, it will have a permanent greenish hue; or if gold, that metal will remain undissolved in the form of a black powder.

The solution should be perfectly clear and colourless; it is caustic, and tinges animal substances of a deep yellow, which, by exposure to light, becomes a deep purple, or black stain, and is indelible, or peels off with the cuticle: it consists of reduced silver. It may be obtained in white crystals, in the form of four and six-sided tables, of a bitter and metallic taste, and soluble in about their own weight of water at 60°. It blackens when exposed to light, and when thus acted upon, is no longer perfectly soluble in water, owing to the separation of a portion of metallic silver.

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* Ann. of Philos. xv. 93.

† *Native Chloride of Silver* has been found in most of the silver mines; it occurs massive and crystallized in small cubes.

Lunar caustic.

1599. When heated in a silver crucible it fuses, and if cast into small cylinders, forms the *lapis infernalis*, or *lunar caustic* of pharmacy; the *argenti nitras* of the *Pharmacopœia.* In forming this preparation, care should be taken not to overheat the salt, and the moulds should be warmed. Exposed to a red heat, the acid is partly evolved and partly decomposed, and metallic silver obtained.*

Action of sulphur, &c.

Exp.

1600. Sulphur, phosphorus, charcoal, hydrogen, and several of the metals, decompose this nitrate. A few grains mixed with a little sulphur, and struck upon an anvil with a heavy hammer, produce a detonation; phosphorus occasions a violent explosion when about half a grain of it is placed upon a crystal of the nitrate, upon an anvil, and struck sharply with a hammer; and if heated with charcoal, it deflagrates, and the metal is reduced.

Exp.

If a piece of silk dipped into a solution of nitrate of silver be exposed while moist to a current of hydrogen gas, it is first blackened, and afterwards becomes iridescent from the reduction of portions of the metal.†

Exp.

A stick of clean phosphorus, introduced into a solution of nitrate of silver, soon becomes beautifully incrusted with the metal, which separates upon it in arborescent crystals. A plate of copper occasions a brilliant precipitation of silver, and the copper is oxidized and dissolved by the acid.

Arbor Dianæ.

1601. The precipitation of silver by mercury is very slow, and produces a peculiar symmetrical arrangement, called the *arbor Dianæ.* It was first remarked by Lemery. To obtain this crystallization in its most perfect state, the solution should contain a little mercury, and the mercury put into it should be alloyed with a little silver.

How made.

Make an amalgam, without heat, of four drachms of leaf silver with two drachms of mercury. Dissolve the amalgam in four ounces or a sufficient quantity of pure nitric acid of a moderate strength; dilute this solution in about a pound and a half of distilled water; agitate the mixture, and preserve it for use in

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* Fused nitrate of silver, according to Proust, is composed of

Silver	64	70
Oxygen	6	
Nitric acid		30
		100

This statement, however, cannot be correct, as it assigns too large a proportion of oxygen to the oxide, viz. 8,6 to 100 grains of silver.

† See Mrs Fulhame's *Essay on Combustion.*

a glass bottle with a ground stopper. When this preparation is to be used, the quantity of one ounce is put into a phial, and the size of a pea of amalgam of gold, or silver, as soft as butter, is to be added; after which the vessel must be left at rest. Soon afterwards, small filaments appear to issue out of the ball of amalgam, which increase and shoot out branches in the form of shrubs. U. 703. According to Proust all that is required is to throw mercury into nitrate of silver very much diluted.

Decomposition.

1602. The alkaline metallic oxides decompose this salt of silver: it is also decomposed by muriatic, sulphuric, phosphoric, and boracic acid. The protosulphate of iron throws down metallic silver when added to a solution of the nitrate: protomuriate of tin forms a grey precipitate consisting of peroxide of tin and oxide of silver.

1603. Ammonia added to solution of nitrate of silver occasions a precipitate soluble in excess of the alkali.

Uses.

Indelible ink.

1604. Nitrate of silver is of much use, as a test for chlorine, muriatic acid, and their compounds. It is employed for writing upon linen under the name of *indelible* or *marking ink*, and is an ingredient in many of the liquids which are sold for the purpose of changing the colour of hair; but, when thus employed, it should be very much diluted, and used with extreme caution, on account of its corrosive quality.

Effect of light.

1605. White paper, or white leather, when stained with a solution of nitrate of silver, in the proportion of ten parts of water to one of the salt, undergoes no change in the dark; but when exposed to the light of day, it gradually acquires colour, and passes through a succession of changes to black. The common sun-beams, passing through red glass, have very little effect upon it; yellow and green are more efficacious; but blue and violet produce the most decidedly powerful effects. Hence this property furnishes a method of copying paintings on glass, and transferring them to leather or paper. The process is described by Mr. T. Wedgwood, in Nicholson's Journal, 8 vo. iii. 167.

Exp.

By a similar process, ivory may be covered with silver. Let a slip of ivory be immersed in a dilute solution of pure nitrate of silver, till the ivory has acquired a bright yellow colour. Then remove it into a tumbler filled with distilled water, and expose it to the direct light of the sun. After two or three hours' exposure, it will have become black; but on rubbing it a little, the surface will be changed into a bright metallic one, resembling a slip of pure silver. As the solution penetrates deep into the ivory, the bright surface, when worn away, is replaced by a succession of others. H. 2. 124.

Nitrite.

1606. *Nitrite of Silver* is obtained, according to Proust, by long digestion of powdered silver in nitric acid already saturated with the metal. It is more soluble than the nitrate, and difficultly crystallizable. It appears not improbable that this salt may contain the suboxide noticed by Mr Faraday. (1587.)

Sulphuret.

1607. *Sulphuret of Silver.*—Silver readily combines with sulphur, and produces a very crystallizable compound, considerably more fusible than silver. It is this which forms the *tarnish* upon silver plate. It has been analyzed by Berzelius, and found to consist of

Silver	87,032	100
Sulphur	12,968	14,9
	100.	114,9

1608. Sulphuretted hydrogen and hydrosulphuret of ammonia occasion a copious black precipitate of sulphuret of silver when added to solutions of the metal; a portion of the silver is frequently at the same time reduced to the metallic state.*

Hyposulphite.

1609. *Hyposulphite of Silver* has been examined by Mr. Herschel in his able paper on the hyposulphurous acid.† It is formed by dropping a weak solution of nitrate of silver into a very dilute solution of hyposulphite of soda; a white cloud is at first produced, which re-dissolves on agitation; on adding more of the precipitant, the cloud re-appears and aggregates into a grey precipitate, which appears to consist of hyposulphite of silver; the supernatant liquor tastes intensely sweet, which is remarkable considering the disgusting bitterness both of the nitrate and of the hyposulphite, and shows, says Mr Herschel, "how little we know of the way in which bodies affect the organs of taste. Sweetness and bitterness, like acidity, seem to depend upon no particular principle, but to be regulated by the state of combination in which the same principles exist at different times."

Hyposulphite of silver is also produced when chloride of silver is dissolved in any of the hyposulphites; the solution is intensely sweet without any metallic flavour.

1610. *Hyposulphite of Potassa and Silver* is formed when liquid potassa is dropped into the solution of chloride of silver in hyposulphite of soda; it separates in the form of a copious precipitate, which, when washed and dried, is found to consist of small grey pearly scales: they are difficultly soluble in water; of a very sweet taste; and heated before the blow-pipe afford a bead of silver.

Sulphite.

1611. *Sulphite of Silver* is obtained in crystalline grains by digesting oxide of silver in sulphurous acid.

Sulphate.

1612. *Sulphate of Silver* is deposited when sulphate of soda is mixed with nitrate of silver. It is also formed by boiling silver in sulphuric acid. It requires about 90 parts of water at 60° for its solution; in boiling water it is more soluble and is deposited, as the solution cools, in small prismatic crystals: it is decomposed at a red heat. It consists of 1 proportional of oxide of silver, and 1 sulphuric acid.

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* For localities, &c. of *Native* Sulphuret of silver, see Cleaveland's Mineralogy.

† Edin. Phil. Journal, i. 26.

1613. A compound acid, which may be called *nitro-sulphuric*, consisting of one part of nitre dissolved in about ten of sulphuric acid, dissolves silver at a temperature below 200°, and the solution admits of moderate dilution before sulphate of silver separates from it. This acid scarcely acts upon copper, lead, or iron, unless diluted with water; it is, therefore, useful in separating the silver from old plated articles: the precious metal may afterwards be separated either in the form of chloride, by adding common salt; or by diluting the acid and continuing the immersion of the pieces of copper which have lost their silvering, and which will now dissolve in the diluted acid and occasion the precipitation of metallic silver.[*]

Phosphate. 1614. *Phosphate of Silver* is a compound of some importance from its use in preparing chloric acid. To obtain it, crystals of nitrate of silver may be dissolved in pure water, and a solution of phosphate of soda be added. The neutrality of the nitrate of silver is destroyed, and though the phosphate contains an excess of alkali, the resulting liquor is acid. The precipitate is of a yellow colour. When washed and dried, it is fusible at a red heat without any farther loss of weight. It consists, according to Berzelius,[†] of

Phosphoric acid	17,025	100
Oxide of silver	82,975	487,38
	100.	H. 2. 128.

Carbonate. 1615. *Carbonate of Silver* is precipitated in the form of a white insoluble powder, by adding carbonate of potassa to nitrate of silver. It blackens by exposure to light. It consists of

1 proportional of carbonic acid . . . . = 22
——— ——— oxide of silver . . . = 117.3

Carbonate of silver = 139.3

1616. Carbonate of ammonia only throws down a portion of the silver from the nitrate, and forms a triple *ammonio-carbonate of silver*.[‡]

1617. The soluble salts of silver are recognized by furnishing a white precipitate with muriatic acid, which blackens by exposure to light, and which is readily soluble in ammonia, and by affording metallic silver upon the immersion of a plate of copper. The salts insoluble in water are soluble in liquid ammosia, and when heated on charcoal before the blow-pipe, they afford a globule of silver.

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[*] Keir, Phil. Trans. lxxx.

[†] Ann. de Chim. et Phys. ii. 163.

[‡] *Borate of Silver* is thrown down from the nitrate of silver in the form of white powder, by adding solution of borate of soda. Hydrocyanic acid and hydrocyanate of potassa cause a white precipitate in solutions of silver, which appears to be a cyanuret of silver, and which, when heated, gives out cyanogen. *Arsenite of Silver* is precipitated in the form of a white powder, soon becoming yellow and brown by the addition of solution of arsenious acid to nitrate of silver. *Arseniate of Silver* is thrown down from nitrate of silver by arsenic acid, of a reddish brown colour. *Chromate of Silver* is precipitated of a crimson colour by adding chromate of soda to nitrate of silver. It soon loses its brilliant tint and becomes brown.

Alloys.

1618. *Alloys of Silver.*—The compounds of this metal with potassium, sodium, and manganese, have not been examined. It unites difficultly with iron.

1619. When silver and steel are fused together, an alloy is formed, which appears perfect while in fusion, but globules of silver exude from it on cooling, which shows the weak attraction of the metals. At a very high temperature the greater part of the silver evaporates, but a portion equal to about 1 in 500 remains, forming a perfect alloy, admirably adapted to the formation of cutting instruments.*

1620. Silver readily combines with zinc and tin, forming brittle alloys. The alloy of silver with copper is of the most importance, as it constitutes plate and coin. By the addition of a small proportion of copper to silver, the metal is rendered harder and more sonorous, while its colour is scarcely impaired. With lead the alloy is grey and brittle, as also with antimony, bismuth, cobalt, and arsenic.

1621. The *standard silver* of Great Britain consists of $11\frac{2}{20}$ of pure silver and $\frac{18}{20}$ copper. A pound troy therefore is composed of 11 oz 2 dwts pure silver, and 18 dwts of copper, and it is coined into 66 shillings. B.

1622. The standard silver of the United States consists of of 1485 parts of fine silver and 179 parts of copper. The dollar contains 416 grains of standard silver, of which $371\frac{1}{4}$ grains are of pure silver, and $44\frac{3}{4}$ grains of alloy. The Troy pound of standard silver contains 10 oz 14 dwts $4\frac{5}{13}$ grs of fine silver, and 1 oz 5 dwts $19\frac{8}{13}$ grs of alloy; and is coined into $13\frac{11}{13}$ dollars; or, 13 oz of standard silver are coined into 15 dollars.

1623. Amalgam of silver is sometimes employed for *plating;* it is applied to the surface of copper, and the mercury being evaporated by heat, the remaining silver is burnished. The better kind of plating, however, is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out.

Silvering for dials.

1624. A mixture of chloride of silver, chalk, and pearlash, is employed for silvering brass: the metal is rendered very clean, and the above mixture moistened with water rubbed upon its surface. In this way thermometer scales and clock dials are usually silvered.

Analysis of alloys.

1625. The analysis of alloyed silver is a very important process, and in continual practice by refiners and assayers. It may be performed in the humid way by dissolving the alloy in nitric acid, precipitating with muriatic acid, and either reducing the chloride by potassa in the way above described (1591), or estimating the quantity of silver which it contains. The usual method, however, which is employed at the mint, and by the refiners, is *cupellation.*

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* Stodart and Faraday, on the Alloys of Steel. *Quarterly Journal*, ix.—*Bost. Jour.* i. 130.

1626. Of the useful metals, there are only three which are capable of resisting the action of air at high temperatures; these are silver, gold, and platinum; the others, under the same circumstances, become oxidized; it might, therefore, be supposed, that an alloy, containing one or more of the former metals, would suffer decomposition by mere exposure to heat and air, and that the oxidable metal would burn away. This, however, is not the case; for if the proportion of the latter be small, it is protected, as it were, by the former; or, in other cases, a film of oxide coats the fused globule, and prevents the further action of the air. These difficulties are overcome by adding to the alloy some highly oxidable metal, the oxide of which is fusible. Lead is the metal usually selected for this purpose, though bismuth will also answer. Supposing, therefore, that an alloy of silver and copper is to be *assayed*, or analyzed by cupellation: the following is the mode of proceeding.

Assaying. A clean piece of the metal, weighing about 30 grains, is laminated, and accurately weighed in a very sensible balance. It is then wrapped up in the requisite quantity of sheet lead, (pure and reduced from litharge,) and placed upon a small *cupel*, or shallow crucible, made of bone earth, which has been previously heated. The whole is then placed under the muffle, heated to bright redness; the metals melt, and by the action of the air which plays over the hot surface, the lead and copper are oxidized and absorbed by the cupel, and a button of pure silver ultimately remains, the completion of the process being judged of by the cessation of the oxidation and motion upon the surface of the globule, and by the very brilliant appearance assumed by the silver when the oxidation of its alloy ceases. The button of pure metal is then suffered to cool gradually, and its loss of weight will be equivalent to the weight of the alloy, which has been separated by oxidation.

To perform this process with accuracy, many precautions are requisite, and nothing but practice can teach these, so as to enable the operator to gain certain results.*

SECTION XXXV. *Gold.*

Native. 1627. GOLD occurs in nature in a metallic state, alloyed with a little silver or copper, and in this state is called *native gold*. Its colour is various shades of yellow; its forms are massive, ramose, and crystallized in cubes and octoëdra. Large quantities of this metal are collected in alluvial soils and in the beds of certain rivers, more especially those of the west coast of Africa and Peru, Brazil, and Mexico. It is found in various

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[*] An excellent article upon the subject will be found in Aikin's *Chemical Dictionary*, and in Mr Children's *Translation of* Thenard *on Chemical Analysis*.

parts of Europe and of North America, especially in North Carolina.*

Method of obtaining pure gold.

1628. Gold may be obtained pure by dissolving standard gold in nitro-muriatic acid, evaporating the solution to dryness, re-dissolving the dry mass in distilled water, filtering, and adding to it a solution of protosulphate of iron; a black powder falls, which, after having been washed with dilute muriatic acid and distilled water, affords on fusion a button of pure gold.

Characters.

1629. Gold is of a deep yellow colour. It melts at a bright red heat, and when in fusion appears of a brilliant green colour. Its specific gravity varies a little according to the mechanical processes which it has undergone; but it may be stated on the average at 19,3.

Gold is so malleable that it may be extended into leaves which do not exceed $\frac{1}{282000}$th of an inch in thickness. It is also very ductile and considerably tenacious; for a wire only $\frac{78}{1000}$ths of an inch in diameter will sustain a weight of 150 lbs.

Fusion of gold.

1630. Gold may be melted by a moderate red-heat, *viz.* at about 32° of Wedgwood's pyrometer. The intense heat of a glass-house furnace has no other effect than to keep it in fusion, and even exposure to Mr Parker's powerful burning lens, for several hours, occasioned no loss of weight. After fusion, it crystallizes in short quadrilateral pyramids. H. 2. 130.

It shows no tendency to unite to oxygen when exposed to its action in a state of fusion; but if an electric discharge be passed through a very fine wire of gold, a purple powder is produced, which has been considered as an oxide.

Action of acids.

1631. Sulphuric, nitric, and muriatic acids, have separately no evident action on gold; but the last mentioned acid, Proust has observed, by long boiling with finely divided gold, dissolves a small portion. Neither does any acid, of which oxygen is the acidifying principle, except concentrated sulphuric and nitric acids, dissolve the oxides of gold, and even those acids do not form permanent compounds. Nitric acid dissolves it only when heated, and deposits it again in the state of a hydroxide on adding water. Sulphuric acid, on the other hand, dissolves oxide of gold at common temperatures, but decomposes the oxide when heated in contact with it.† H. 2. 130.

Oxides.

1632. *Gold and Oxygen.* The best process for obtaining *oxide of gold*, according to Pelletier‡ is to precipitate chloride of gold by magnesia. Muriate of magnesia is formed, which may be removed by washing, and the excess of magnesia may be dissolved by diluted nitric acid. In this case, the magnesia is doubtless converted into a chloride, and parts with its oxygen to the gold. The oxide must be dried at a very low heat.

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* For an account of the gold mines of North Carolina see American Journal of Science ix. 5.—The quantity of gold from North Carolina deposited for coinage in the U. S. mint, during the year 1825, amounted to about 17,000 dollars in value.

† Pelletier, *Ann. de Chim. et Phys.* xv. 11.

‡ *Ann. de Chim. et Phys.* xvi. 5.

Composition of the oxides.

1633. There is considerable disagreement as to the composition of the oxides of gold. Oberkampf* deduces as a mean of three experiments, that 100 parts of gold unite with 10,01 oxygen; Berzelius makes the proportion of the latter at 12,07; and Pelletier, from the composition of the iodide deduces it to be 10,03. This is assigned as the composition of the peroxide; but besides this, he supposes that there is a protoxide containing only one third of the oxygen which exists in the peroxide. Their composition may, therefore, according to Pelletier, be stated as follows:

	Metal.		Oxygen.
Protoxide	100	+	3,3495
Peroxide	100	+	10,03.

H. 2. 134.

Action of chlorine.

1634. *Chloride of Gold.*—When gold in a state of minute division, or gold leaf is heated in chlorine, a compound of a deep yellow colour results, which is said to consist of one proportional of each of its constituents.

According to Pelletier there are two chlorides of gold.

		Metal.		Chlorine.
The protochloride, or subchloride .	=	100	+	14,715
The perchloride (soluble)	=	100	+	44,145

It is in the state of perchloride that gold exists when dissolved in *aqua regia*. H. 2. 132.

Action of iodine.

1635. The action of *iodine* on gold has been examined by M. Pelletier.† When hydriodate of potassa is added to chloride of gold, it produces a very copious yellowish brown precipitate, insoluble in cold water, and easily decomposed by heat. It gave on analysis

Iodine	34
Gold	66

Nitrate.

1636. *Nitrate of Gold.*—The nitric acid has scarcely any action upon gold, but it readily dissolves the oxide, forming a yellow styptic deliquescent salt.

Solvents.

1637. The true solvents of gold are solution of chlorine and nitro-muriatic acid; the latter is usually employed, composed of two parts of muriatic and one of nitric acid. By evaporation, the saturated solution, which, however, is always acid, affords prismatic crystals of *chloride of gold*. This salt is very deliquescent; it is decomposed by heat, leaving a spongy mass of pure gold; a very minute portion of the metal also passes off with the muriatic acid.

Triple chloride of gold and potassa.

1638. When potassa is added to the solution of chloride of gold, no precipitate occurs till heat is applied, when a reddish yellow precipitate falls, which is peroxide of gold; the whole of the metal, however is not thrown down, a portion being retained so as to form a *triple chloride of gold and potassa,* which is very soluble and not decomposed by further excess of alkali, it is on this account that a very acid solution of chloride of gold will afford no precipitate whatever with potassa or soda, the triple salt formed being in that case sufficient to employ the whole of the oxide of gold. B.

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* Ann. de Chim. lxxx.

† Quarterly Journal of Science and Arts, x. 121.

Aurate of potassa.

If a considerable excess of potassa be mixed with the chloride of gold, the supernatant liquid acquires a greenish yellow, and a blackish sediment is formed, in which not more than $\frac{1}{10}$th of the gold is found that was held in solution. The remaining $\frac{9}{10}$ths, united with oxygen, have combined with the potassa, which acts the part of a base, while the oxide of gold serves as a salifying principle. To this compound Pelletier gives the name of *aurate of potassa.* Oxide of gold appears therefore adapted to unite with bases, rather than itself to form a base for combination with acids, with most of which it refuses to unite. H. 2. 135.

Triple chloride of gold and sodium.

1639. When common salt is added to the solution of gold in nitro-muriatic acid, and evaporated to dryness, a *triple chloride of gold and sodium* is obtained which is the *Auri murias* of the Pharmacopœia. It was first formed by M. Chretien[*] and has been examined by M. M. Figuier and Berard.[†] It crystallizes in long four sided prisms, of a beautiful orange colour, which are not altered by exposure to the air. Its composition is stated by Dr Thomson as follows.

Composition.

Gold	25
Chloride of Sodium	7,5
Chlorine	9
Water	9
	50,5[‡]

Fulminating gold.

1640. A solution of pure ammonia separates, from the solution by nitro-muriatic acid, an oxide of gold, and a portion of ammonia, uniting with the oxide, forms a compound, which detonates very loudly in a gentle heat, and is termed *fulminating gold.*

To obtain this compound, add a solution of ammonia in water, or the pure liquid ammonia, to diluted chloride of gold; a precipitate will appear, which will be re-dissolved if too much alkali be used. Let the liquor be filtered and wash the sediment which remains on the filter with several portions of warm water. Dry it by exposure to the air, without any artificial heat, and preserve it in a bottle, closed, not with a glass stopper, but merely by a cork. A small portion of this powder, less than a grain in weight, being placed on the point of a knife and held over a lamp, detonates violently. The precise temperature which is required is not known, but it appears to exceed 250° Fahrenheit. At the moment of explosion, a transient flash is observed. Two or three grains, exploded on a pretty strong sheet of copper, will force a hole through it. Neither electricity nor a spark from the flint and steel are sufficient to occasion its detonation; but the slightest friction explodes it, and serious accidents have happened from this cause.

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[*] See Bigelow's *Sequel*, 92.

[†] *Jour. de Pharmacie*, vi. 64.

[‡] *First Principles*, i. 445.

Theory.

This detonation is explained as follows; Fulminating gold is an oxide of that metal, combined with ammonia. When its temperature is raised, the ammonia is decomposed; the hydrogen of the alkali unites with the oxygen of the oxide, and reduces the gold to a metallic state; and nitrogen gas, and probably aqueous vapour, are liberated in a highly expanded state. The violent impulse of these aëriform products, on the surrounding atmosphere, appears to be the cause of the loud noise that is occasioned by the explosion of this compound.

Revival of gold from solutions.

1641. The solution of chloride of gold is decomposed by certain combustible bodies, which appear to act by furnishing hydrogen to the chlorine, and reduce the gold to a metallic form, as in the following examples:

Exp.

Into a dilute solution of chloride of gold, contained in a glass jar, put a long narrow slip of charcoal, and expose the whole to the direct light of the sun. The gold will be revived, and will appear on the charcoal in a metallic state, exhibiting a very beautiful appearance. The same change ensues without light, if the solution be exposed to a temperature of 212°.

Exp.

Moisten a piece of white taffeta riband, with the dilute solution of gold, and expose it to a current of hydrogen gas from iron filings, and dilute sulphuric acid. The gold will be reduced, and the riband will be gilt with the metal. By means of a camel's hair pencil, the gold may be so applied as to exhibit regular figures, when reduced.

The same experiment may be repeated substituting phosphuretted hydrogen for common hydrogen gas.*

Decomposed by vegetable acids.

1642. Several of the vegetable acids, but particularly the oxalic, decompose chloride of gold at common temperatures, especially if exposed to the sun's rays. The bin-oxalate of potassa is still more efficient; an effervescence arises from the escape of carbonic acid; and in about an hour all the gold is revived.† Tartaric acid does not produce the same effect, but bi-tartrate of potassa occasions a decomposition, though less rapid. Acetic acid may be mingled with chloride of gold without producing any change.

1643. Gold is precipitated from its solution in a metallic form, by a solution of green sulphate of iron. This depends on the affinity of the protoxide of iron for a farther quantity of oxygen, which it takes from the oxide of gold.

Purple of Cassius.

1644. When a sheet of pure tin is immersed in a solution of nitro-muriate of gold, the oxide of gold is precipitated of a purple colour; and, when scraped off and collected, forms the *purple powder of Cassius*, much employed in enamelling. Or the metallic salt, largely diluted with water, may be put into a glass vessel with a few pieces of grain tin. In a short time, the liquor will become of the colour of red wine, and a very light floculent precipitate will begin to precipitate, leaving the liquor clear. This, when well washed and dried, has a deep purple colour, and is the precipitate of Cassius. The same precipitate is obtained by mixing a solution of gold with a recently made solution of tin in muriatic acid.

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* For a detail of various experiments of a similar kind consult an Essay on Combustion, by Mrs. Fulhame; also Count Rumford's paper, in the Philosophical Transactions, 1798, page 449.

† Van Mons.

1645. The composition and colour of the precipitates of gold, thrown down by muriate of tin at the minimum, have been shown, by Oberkampf, to be variable. The colour approaches more to a violet, as the salt of tin bears a larger proportion to that of gold; and the colour communicated by the precipitate to porcelain, has the same variable character. When the muriate of gold is in excess, the precipitate has more of a rose colour. H. 2. 135.

Ethereal solution of gold.

1646. If a solution of chloride of gold be mixed with sulphuric ether it combines with the oxide, and an *ethereal solution of gold* is obtained. Polished steel dipped into this solution acquires a coat of gold, and it has hence been employed for gilding delicate cutting ornaments.*

Sulphuret.

1647. *Sulphuret of gold* is procured by passing sulphuretted hydrogen through an aqueous solution of gold. It is a black substance, and is a true sulphuret, which gives up its sulphur on the application of heat. It is composed of

Gold	80,39	100
Sulphur	19,61	24,39
	100.	124,39

The sulphuret of gold is soluble in hydro-sulphuret of potash. Liquid potash takes up a part, and leaves a yellow powder, which is metallic gold. The alkaline hydro-sulphurets do not dissolve gold, however minutely divided, till sulphur is added, when probably a sulphuret of gold is formed, on which the hydro-sulphuret is capable of acting. H. 2. 137.

Phosphuret.

1648. *Phosphuret of gold* is obtained by heating gold leaf with phosphorus, in a tube deprived of air. It is a grey substance of a metallic lustre, and consists probably of 1 proportional gold + 1 phosphorus.

Equivalent number for gold.

There is considerable difficulty in fixing upon a number to represent the weight of the atom of gold, on account of the uncertainty respecting the smallest proportions of oxygen, chlorine, &c. with which it is capable of forming a chemical compound. It appears that the only well-ascertained oxide of gold is that which contains, according to Oberkampf, 10,01, and to Berzelius, 12,07 oxygen, on 100 of the metal; and if this be the only oxide, the atom of gold will be represented either by 80, or by 70, as we take the experimental result of the former, or the

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‡ See *Sulphuric Ether*.

latter chemist. The constitution of the protoxide, as stated by Pelletier, would raise the representative number to 240; that of iodide to 242; and that of proto-chloride to 244; but the existence of an oxide and a chloride with so small a relative proportion of oxygen and chlorine, has not yet been sufficiently established. The composition of the oxide, assigned by Berzelius, is confirmed by Oberkampf's analysis of the sulphuret, viz. 100 metal and 24,39 sulphur; for this agrees with the relative atomic weights of oxygen and sulphur, the latter of which is shown, by a variety of well-ascertained facts, to be double that of the former. The whole subject appears, however, to require farther investigation, before an equivalent number can be obtained for gold entitled to our full confidence. H. 2. 137.

Alloys.

1649. *Alloys of Gold.*—A very curious detail of an extended and accurate series of experiments upon the alloys of gold has been published in the *Philosophical Transactions* for 1803, by Mr. Hatchett: his experiments were generally made with 11 parts of gold and 1 of alloy; or 38 grains of alloy to the ounce of gold.

With potassium, &c.

1650. The alloys of gold with potassium, sodium, and manganese, have not been examined. With iron the alloy is malleable and ductile, and harder than gold, its colour dull white, and its specific gravity 16,885. The metals expand by union, so that supposing their bulk before combination to have been 1000, after combination it is 1014,7.

—with zinc.

1651. With zinc the compound is brittle and brass-coloured. Specific gravity 16,937. The metals contract a little in uniting, the original bulk being 1000, that of the alloy is 997. The brittleness continued when the zinc was reduced to $\frac{1}{56}$ of the alloy. The fumes of zinc in a furnace containing fused gold, make it brittle.

—with tin.

1652. Tin formed a whitish alloy, brittle when thick, but flexible in thin pieces. Specific gravity 17,307. Bulk before fusion 1000; after fusion 981. So that there is considerable contraction. The old chemists called tin *diabolus metallorum*, from its property of rendering gold brittle, but Mr Bingley's experiments quoted by Mr Hatchett, show that $\frac{1}{60}$ of tin does not render gold brittle.

—with lead.

1653. The alloy of lead is very brittle when that metal only constitutes $\frac{1}{1920}$ of the alloy; even the fumes of lead destroy the ductility of gold. The specific gravity 18,080; and 1000 parts become 1005. A very remarkable fact in respect to this alloy is, that its specific gravity diminishes, to a certain extent, as the proportion of lead diminishes, and is at its maximum when the lead amounts only to $\frac{1}{960}$th part, the quantity of gold remaining the same, and the deficiency being made up with copper.*

—with copper.

1654. With copper (standard gold) the alloy is perfectly ductile and malleable, but harder than pure gold, and resists wear better than any other alloy except that with silver. Its specific gravity is 17,157. The gold coin of Great Britain is an alloy of eleven parts of gold and one of copper; of this alloy, twenty troy pounds are coined into 934 sovereigns and one half sovereign; one pound formerly was coined into 44½ guineas; it now produces $46\frac{29}{40}$ sovereigns being melted, or alloyed with copper.

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* A table exhibiting this remarkable fact has been drawn up by Mr Hatchett. See *Tables.*

Gold coins of G. Britain.

Gold coins of United State.

1655. The standard of the gold coins of the United States consists of 11 parts of fine gold to 1 part alloy, which alloy consists of silver and copper in any convenient proportion, provided the silver do not exceed the copper. The eagle of ten dollars contains 270 grains of standard gold, of which 247½ grs. are fine gold, and 22½ grs. alloy. The troy pound of standard gold contains 11 ozs of fine gold and 1 ounce of alloy, and is coined into 21⅓ eagles, of the value of 213⅓ dollars; or 9 ounces of standard gold are coined into 16 eagles of the value of 160 dollars.[*]

1656. Arsenic and antimony, when alloyed in very small proportions with gold, destroy its colour and render it quite brittle.

Analysis of alloys of gold.

1657. The analysis of most of the alloys of gold is performed by cupellation. The triple alloy of gold, silver, and copper, may be analyzed by digesting it in nitric acid, which takes up the silver and copper, and leaves the gold in the form of a black powder, which may be fused into a button, and weighed. The silver may be thrown down in the state of chloride by solution of common salt, and the copper precipitated by iron.

Assay.

1658. The assay of gold is more complicated than that of silver, in consequence of the high attraction which it has for copper, and which prevents its complete separation by mere cupellation. An alloy, therefore, of copper with gold, is combined with a certain quantity of silver, previous to cupellation; this is then cupelled with lead in the usual way, and the silver is afterwards separated by the action of nitric acid.

1659. The real quantity of gold or silver taken for an assay is very small; from 18 to 36 grains, for instance, for silver, and from 6 to 12 for gold; whatever the quantity may be it is called the *assay pound*. The silver assay pound is divided into 12 ounces, and each ounce into 20 penny-weights. The gold assay pound is subdivided into 24 carats, and each carat into 4 assay grains.[†]

Water gilding.

1660. Mercury and gold combine with great ease, and produce a white amalgam much used in gilding. For this purpose the amalgam is applied to the surface of the silver; the mercury is then driven off by heat, and the gold remains adhering to the silver, and is burnished. This process is called *water gilding.*

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[*] The proportional value of fine gold to fine silver by the laws of the United States, is as 15 to 1; so that 1 pound of fine gold is worth 15 pounds of fine silver. The proportional value of the different gold and silver coins is derived wholly from the proportion of fine gold in the one, to the fine silver in the other, the alloy in both being disregarded. Thus 24 3-4 grains of fine gold, being one tenth of the fine gold in our eagle are equivalent to our dollar and multiplied by 15 produce 371 1-4, the grains of fine silver in the dollar.

[†] Aikin's *Dictionary*. Art. *Assay*.

In gilding porcelain *gold powder* is generally employed, obtained by the decomposition of the chloride; it is applied with a pencil, and burnished after it has been exposed to the heat of the porcelain furnace.

The degree of purity of gold is expressed by the number of parts of that metal, contained in the 24 parts of any mixture. Thus, gold, which in 24 such parts (termed *carats*,) contains 22 of the pure metal is said to be 22 carats fine. Absolutely pure gold, using the same language, is 24 carats fine; and gold alloyed with an equal weight of another metal, 12 carats fine.[*]

SECTION XXXVI. *Platinum.*

Native.

1661. THE original repositories of *native platinum* are not known, it having hitherto been found only in pebbles and grains,[†] generally small, but sometimes upwards of a pound and a half in weight. It is principally found in South America, in the provinces of Choco and Barbacoas, also at Matto Grosso in Brazil. It has also been found in St Domingo.[‡]

Mode of obtaining.

The pure metal may be obtained by dissolving crude platinum in nitro-muriatic acid, and precipitating by a solution of muriate of ammonia. This first precipitate is heated, dissolved in nitro-muriatic acid, and again precipitated as before. The second precipitate is heated white hot, and pure platinum remains.[§] It is a white metal. Its specific gravity is 21,5.[‖]

Fused by the blow-pipe.

1662. It is very difficult of fusion, but may be melted by the blow-pipe, with the aid of oxygen gas. A globule weighing 29 grains, boiled violently in the focus of a lens about three feet in diameter;[¶] and by means of the oxy-hydrogen blow-pipe more than 200 grains have been kept boiling for some time.

Unaltered by air and heat.

1663. It is unaltered by the joint action of heat and air. It is very ductile and may be drawn into wire about the 2000th part of an inch in diameter. It is malleable and may be beaten into very thin plates, called *platina foil.*

May be welded.

1664. In common with iron, platinum has the property of welding,[**] which is peculiar to these two metals. It may, also, be united by welding, with iron and steel.

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[*] Many curious facts relating to the properties of gold, and its uses in the arts, will be found in Dr Lewis's *Philosophical Commerce of the Arts.*

[†] Mohs' Mineralogy, ii. 441.

[‡] These grains, besides platinum, contain generally gold, iron, lead, palladium, rhodium, iridium, and osmium.

[§] Various processes have been given for obtaining pure platinum, for which, see Aikin's *Dictionary*, article Platinum; Ure's *Dictionary*, p. 640; *Quarterly Jour.* xii. 247. Thenard, *Traite de Chim.* iii. 479, edit. 4.

[‖] 17,332 (rolled masses) Mohs.

[¶] *Ann. de Chim.* lxix. 93.

[**] Two pieces of wrought iron, raised to a white heat become covered with a kind of varnish; and, when brought into contact, may be permanently united by forging. This is called the welding of iron.

Power of conducting heat.

1665. Platinum has been discovered by Dr Wollaston to be a remarkably slow conductor of heat. Its expansion by heat is considerably less than that of steel. From the experiments of Mr Scott of Dublin it appears to possess sufficient elasticity to be applicable to making of pendulum springs for watches.* H. 2. 140.

Oxides.

1666. *Platinum and Oxygen.*—Two oxides of platinum have been described by Berzelius.† The protoxide is precipitated from the chloride by excess of potassa, it is of a black colour, and consists of

Platinum	92,35	100,
Oxygen	7,65	8,287
	100,	108,287

The peroxide, according to the same chemist, has been obtained only in combination. It is composed of

Platinum	85,93	100,
Oxygen	14,07	16,38
	100,	116,38

Protoxide.

1667. By pouring a neutral protonitrate of mercury into a dilute solution of chloride of platinum in hot water, Mr Cooper obtained what he considers the *protoxide of platinum.* The precipitate, a mixture of calomel and protoxide of platinum, after being carefully washed and dried, was exposed to a heat barely sufficient to raise the calomel, after which there remained an intensely black powder. By distillation Mr Cooper ascertained that this powder is composed of 100 parts of platinum + 4,517 oxygen.‡ It has been objected, however, by Berzelius, and Mr E. Davy that the temperature required to sublime calomel is sufficient to deprive oxide of platinum of part of its oxygen; and, therefore, that the true composition of the protoxide cannot be determined by Mr Cooper's method.

Objected to by Berzelius and Davy.

1668. According to Vauquelin, the oxide of platinum, obtained from the chloride by means of soda is constituted of 100 metal + 15 or 16 oxygen.§

Deutoxide of Mr Davy.

1669. Another oxide has been described by Mr E. Davy, which appears to be intermediate between the peroxide, as stated by Berzelius and Vauquelin, and the protoxide of the former chemist. It was formed by boiling together strong nitric acid, and fulminating platinum (1677), drying the product, and heating it just below redness; then washing with water, and finally with a little potassa. Its colour was dark iron grey; it was not affected by water, either hot or cold; nor by nitrous, sulphuric or phosphoric acids; it was insoluble in nitro-muri-

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* Nicholson's *Journal*, xxii. 148.

† Ann. de Chim. 87. 126.

‡ Quarterly Journal, iii.

§ Ann. de Chim. et Phys. v.

Professor Dana has found that spongy platinum is also ignited by the vapour of alcohol or ether.*

Soda-muriate.

1672. The solution of platinum forms a triple combination with soda, or *soda-muriate*. This is best obtained by adding to nitric acid, in a retort, platinum, with twice its weight of muriate of soda, and applying heat till about four fifths of the fluid have come over. The remaining liquor forms, on cooling, fine prismatic crystals, sometimes four or five inches long; and either reddish brown, like titanium; yellow like amber, or of a beautiful coquelicot colour.† H. 2. 143.

1673. Ferrocyanate of potassa affords no precipitate with solution of chloride of platinum. The addition of potassa occasions a precipitate of a triple compound of the alkali and acid.‡ Sulphuretted hydrogen occasions a black precipitate. Ether separates the oxide of platinum in the same way as that of gold. Muriate of tin occasions a very characteristic red precipitate in very dilute solution of platinum.

A solution of platinum, so dilute, as to be scarcely distinguishable from water, assumes a bright red colour, on the addition of a single drop of the recent solution of tin.

Sulphurets.

1674. There are, according to Mr E. Davy, three *sulphurets of platinum*. The first, formed by heating the finely-divided metal with sulphur; the second, by precipitating nitro-muriate of platinum by sulphuretted hydrogen; and the third, by heating 3 parts of the ammonio-muriate with 2 of sulphur.

1675. According to the same authority there are two phosphurets. The first, obtained by heating phosphorus with the metal; the second, by heating phosphorus with the ammonio-muriate of platinum.

Sulphate.

1676. The salts of platinum have been but little examined. Proust and Davy have described a *sulphate*, obtained by acidifying the sulphur in the sulphuret by means of nitric acid. It is of a brown colour, and very soluble; and with soda, potassa, and ammonia, it forms triple salts.

Mr Davy finds the solution of the sulphate in water to be an excellent test for discovering gelatine.

Fulminating platinum.

1677. Mr E. Davy found that the precipitate by a slight excess of ammonia, when boiled in potassa, washed and dried, was a *fulminating platinum;* it explodes at about 420°, with a very loud report.§ One grain laid on a thin sheet of copper and exploded produces a report louder than that of a pistol, and the copper is deeply indented. Like fulminating gold, it is incapable of being exploded by percussion.

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* Amer. Jour. &c. viii. 198.

† Nicholson's *Jour.* 8vo. ix. 67.—According to Dr Thomson it is composed of

Platinum	1 Atoms.	
Chlorine	2	
Chloride of sodium	1	
Water	8	*First Prin.* i. 454.

‡ Or *Potassa-muriate.* H.

§ Phil. Trans. 1817.

1678. A very singular compound of platinum is described by Mr E. Davy, in the *Philosophical Transactions* (1820, p. 108), obtained by mixing equal volumes of strong aqueous solution of the sulphate and of alcohol. The colour of the sulphate slowly disappears, and in some days a black substance subsides, which is washed and dried. It is also formed by boiling the sulphate and alcohol together for a few minutes. This substance is permanent in the air and insoluble in water. It detonates feebly when heated, and is not affected by chlorine, nor by nitric, sulphuric, and phosphoric acids; but it is slowly soluble in muriatic acid. Put into liquid ammonia it acquires fulminating properties, and plunged into the gas it becomes red hot: the same phenomenon is exhibited by exposing it to the vapour of alcohol, or by placing it upon a piece of paper moistened with that fluid: in these cases the platinum is reduced with the evolution of heat, and the ignition seems to depend upon the slow combustion of the vapour of the alcohol, as has been elsewhere shown. (181.) From Mr Davy's analysis of this compound, it appears to contain 96,25 platinum, 0,12 oxygen, 0,0106 carbon 3,6194 nitric acid and water; the acid being derived from the mode of preparing the sulphate.

1679. The alloys of platinum are not, in general, characterized by useful properties. Its affinity for lead is strikingly shown by the following experiment. If a piece of lead foil, and another of platinum foil, of equal dimensions, be rolled up together, and the flame of a candle be cautiously directed by a blow-pipe towards the edges of the roll, at about a red heat, the two metals will combine with a sort of explosive force, scattering their melted particles, and emitting light and heat in a surprising manner.* A small bit of tin, zinc, or antimony, rolled in platinum leaf, and treated in the like manner, exhibits similar appearances. Alloys.

1680. Zinc, bismuth, tin, and arsenic, readily combine with platinum, and form fusible alloys. It also unites, though less readily, with copper, lead and iron. It combines with gold, and unless there be great excess of the latter, the colour of the alloy resembles platinum.

1681. By combining 7 parts of platinum with 16 of copper and 1 of zinc, Mr Cooper obtained a mixture much resembling gold.† Sixteen parts by weight of pure platinum, seven parts of copper, and one of zinc equally pure, mixed together in a crucible, and covered with charcoal powder, when perfectly fused form an alloy which has been called by Dr Hermstadt *artificial gold.* It nearly resembles gold in specific gravity, colour and ductility.

1682. The alloys of steel and platinum have been examined by Stodart and Faraday. They combine in all proportions, but from 1 to 3 per cent. of platinum appears best adapted for cutting instruments. Equal weights of the two metals produce a fine hard and brilliant alloy of a specific gravity of 9,862; it appears well adapted for mirrors, for it takes a fine polish and does not tarnish. An alloy of 90 platinum and 20 steel has a specific gravity of 15,88.

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* Ann. of Philos. xiv. 230.

† Quart. Jour. iii. 119.

1683. Wires of steel and platinum, when welded and polished, exhibit a curious and beautiful surface, especially when the steel parts are slightly acted upon by dilute acid. The welding property of platinum may be usefully applied in the arts; rings may be joined so as to form a chain, the durability of which must add to its value; and with a view to economy, platinum may be joined to iron or steel for many uses in the laboratory of the chemist.

Section XXXVII. *Silicium.*

1684. In attempting to decompose silica, and to obtain its base in a state of perfect separation, Sir H. Davy was unsuccessful, but the results of his experiments left little doubt that this earth is like the rest compounded of oxygen and a peculiar base. Berzelius has since decomposed silica, by fusing it with charcoal and iron in a blast furnace; and more recently by exposing the fluate of silica and potassa to heat along with potassium.

How obtained.

1685. It may be obtained more easily by decomposing the fluate of silica and soda, which has the advantage of containing under the same weight and volume a greater quantity of the fluate of silica. This desiccated salt is reduced to a fine powder* and put by layers with potassium into a tube of glass closed at one end, which is so placed that all the mass may be heated at the same time. We may if we choose, melt the potassium and mix it by means of a rod of iron, with the salt, and then heat the mass over a spirit-lamp. Even before a red heat, the silicium is reduced with a slight hissing and a feeble appearance of heat. The mass is left to cool, and subsequently washed in a large quantity of cold water. A brown powder is obtained which should be boiled with water, and washed with hot water until no stain is left by the evaporation of a drop of the liquid.

The substance washed is a *hydruret* of silicium which is to be heated in an open crucible nearly to redness for some time, and then raised slowly to a perfect red heat. The hydrogen is burned off and pure silicium remains. If the silicium become inflamed, the crucible should be covered directly and the temperature lowered, which will instantly stop the combustion. When the calcination is finished, the silicium is incombustible in air, and is no longer attacked by fluoric acid, if pure. The small quantity of silica produced may be dissolved in fluoric acid. After treatment by the acid the silicium is washed and dried.*

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* In case the desiccation has made the particles adhere, and to expel the humidity that may remain, it should be exposed to a temperature, as high as it can bear without being decomposed.

Properties.

1686. Obtained in the manner described, silicium is of a dark nut-brown colour, without the least metallic lustre. It is obtained in various states of aggregation, and its combustibility varies accordingly; in this respect it much resembles carbon.

1687. In the state of least condensation, in which it is obtained when just separated from the potassium by means of water, it is combustible in atmospheric air, and in oxygen gas. But in its densest state it may be made incandescent in the air without burning; it does not undergo any change in the flame of the blow-pipe, and appears to belong to the class of the most infusible bodies. This difference in its combustibility is extremely remarkable.

Action on glass, &c.

1688. Silicium, even when dry, stains and strongly adheres to the glass vessels in which it is kept. When treated with fluoric acid, the liquid is covered with a slight pellicle, which envelopes each drop that is taken from it. It is a non-conductor of electricity. It is not attacked by nitre until the temperature is raised sufficiently high to decompose the nitric acid; but at a white heat it is acted upon with great energy by that salt.

Burns with carbonate of potassa.

1689. With carbonate of potassa it burns vividly, carbonic oxide being given out, and the reduced carbon imparting a black colour to the mass. When the portion of carbonate is equal in bulk to half the silicium the inflammation takes place much below the temperature of ignition. With greater quantities the mass becomes distended, by the production of carbonic oxide, takes fire and burns with a blue flame. If a still greater quantity of carbonate be employed, no signs of combustion can be perceived; the mass does not grow black, and merely gives out carbonic oxide.†

1690. Silicium detonates with the hydrates of the fixed alkalies, producing a vivid incandescence at a temperature at which they melt, but much below that of ignition. Hydrogen gas is given out, which is seen to burn when the bulk of the mass is not too small. The same phenomena are observed with the hydrate of baryta. Incandescence also takes place with the hydrate of lime; but it is very feeble, and the silicium is oxidated but imperfectly. With the acid fluate of potassa it detonates at the fusing temperature of the salt, that is to say, much below a red heat; it is not affected by fused borax.

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* For more minute details see the memoir of Berzelius in the *Annales de Chim. et Phys.* xxvii. 337. or *Boston Journal of Philos.* iii. 37.

† From this mode of action of silicium with carbonate of potassa arises a very paradoxical phenomenon. If some incombustible silicium is heated with saltpetre to a moderate red, on a leaf of platinum or in a little crucible, no action will be observed; but if there be added a little dry carbonate of soda, so that it may touch the silicium, a detonation will take place, at the expense of the carbonate in the midst of the saltpetre, and the mass will preserve for some time its black colour. *Berzelius.*

Sulphuret. 1691. Silicium heated to a perfect red in the vapour of sulphur inflames and burns, but with less intensity than in oxygen; and the combination even does not take place with the incombustible silicium. The sulphuration is usually as incomplete as the oxidation, and a scorified mass is obtained of a dark grey colour. It sometimes happens, however, particularly when a vacuum is made in the vessels before volatilizing the sulphur, that the silicium becomes completely sulphuretted, at least in a part of its mass. It then presents an earthy white body, which, thrown into water, instantly dissolves in it with the evolution of sulphuretted hydrogen. The silicium is converted into silica which dissolves in the water; and if this is in small quantity, a solution may be obtained so much concentrated, that it solidifies after a slight evaporation, and it leaves the silica, after the desiccation, in a transparent fissured mass. Silicium imperfectly sulphuretted also decomposes water rapidly, with disengagement of hydrogen, and solution of the silica in the water; and the silicium which was not combined with the sulphur becomes separated. In the air the sulphuret of silicium diffuses a very strong smell of sulphuretted hydrogen, and loses in a little time all its sulphur; but in dry air it may be preserved a long time. At a red heat, it contracts and shrivels up, yielding sulphurous acid and silica. This change, however, takes place but slowly; for when kept at a red heat for some moments, it still has the property of decomposing water.

1692. The siliciuret of potassium readily combines with sulphur at a red heat; but if the mass is dissolved in water, there remains much silicium, unless the mass be newly exposed to a white heat, the silicium then combining with the sulphur at the expense of the potassium previously sulphuretted at a more elevated temperature. This combination is a true double sulphuret; its colour is of a dark brown, almost black. It presents a melted mass which dissolves in water. The combinations of the sulphuret of silicium with the metallic sulphurets, although they exist in the dry way, cannot, it appears, exist in water.

Action of chlorine. 1693. If silicium is heated in a current of chlorine, it takes fire and continues to burn. If the gas contains atmospheric air, some silica remains in the form of a slight skeleton. Silicium burns equally well in chlorine, whether or not it has lost its combustibility in the air. The product condenses and presents a yellowish liquid when it contains an excess of chlorine, but which is without colour when it is freed from this excess. This liquid is very fluid; it evaporates almost instantaneously when exposed to the air, yielding white vapours, and leaving a residuum of silica. It has a very penetrating smell, which may be compared in some degree to that of cyanogen. Thrown into water, it floats on the top; it generally dissolves in it, or leaves a little silica. If the quantity of water is small, a drop, for example, on as much chloride of silicium, this envelopes it, and the silica remains in a frothy semi-transparent mass. This liquid is analogous to the combinations of the other electro-negative bodies with chlorine.

—of potassium.

1694. At common temperatures potassium has no action on chloride of silicium; but when heated in the vapour of the latter substance it takes fire and produces a compound of potassium and silicium. The *iodide* of potassium does not combine with silicium.

—of acids.

1695. Silicium is neither dissolved nor attacked by the sulphuric, nitric, or muriatic acids, and not even by nitro-muriatic acid. In its combustible state it is slowly dissolved by fluoric acid with the evolution of hydrogen; but in losing its combustibility, it loses also the property of dissolving in this acid. It is, on the contrary, dissolved with rapidity, even in the cold, by a mixture of the nitric and fluoric acids, nitrous gas being given out. Combustible silicium is dissolved by digestion in a solution of caustic potassa; but when rendered incombustible, it is no longer attacked by the alkalies in the humid way.

Alloys.

1696. Silicium, when once isolated, combines with the metals with much difficulty. Its remarkable affinity for platinum is known by the experiments of M. Boussingault; but it may be heated as often and as long as we choose in a platinum crucible, without any combination taking place. But if we endeavour to reduce silicium by potassium in a platinum crucible, the silicium penetrates deeply into the platinum wherever this is touched by potassium. Copper, silver, lead, and tin, heated with silicium by the blow-pipe, do not seem changed in their appearance, nor in their ductility; notwithstanding when they are treated with acids they leave a small quantity of silica.

Silicium combines with potassium at a high temperature, but without the evolution of a remarkable heat. It affords two combinations; one with excess of potassium, of a dark-grey, and which dissolves completely in water; the other, with less potassium,. is obtained by the reduction before stated, or by exposing the first to a very strong heat.

Oxidation of silicium.

1697. M. Berzelius endeavoured to ascertain the composition of *silica* by effecting the oxidation of silicium in a direct manner. For this purpose 100 parts of pure silicium were burnt with carbonate of soda. The mass, treated by muriatic acid, evaporated to dryness, and strongly heated, was dissolved in water, and left some silica coloured grey by carbon, which, well washed and ignited, became snow-white, and weighed 203,75. The solution obtained and the waters of the washing were evaporated afresh, and the saline residuum heated to redness. Treating this with water it still gave a little silica, which, after the addition of a drop of ammonia, took at the expiration of some hours a colour inclining to a yellowish-brown; when heated to redness it weighed 1,5; it had lost its dark colour, but it was not snow-white. With soda it gave on platinum foil a faint but evident trace of manganese. 100 parts of silicium had consequently absorbed 105,25 of oxygen, and produced 205,25 of silica. The experiment was repeated on a portion of silicium on which fluoric acid had been evaporated, in order to be more certain that all the silica had been removed. 100 parts of silicium, previously calcined to redness in the air, gave, by the process described above, 202 of silica; and by evaporation of the waters, 1 part; or in all 208 of silica.

Composition of silica.

According to these two experiments silica is composed of

Silicium . . . . 48,72 to 48,08.
Oxygen . . . . 51,28 to 51,92.

1698. It still remains to be decided to what class of simple bodies silicium belongs. Since it has no lustre, nor the property of conducting electricity in the state in which it has hitherto been obtained, its properties bring it near to boron and carbon. Carbon possesses the metallic lustre, and conducts electricity, but it is not considered as a metal; and if silicium could be melted, it then perhaps would have these properties, which it does not possess in a pulverulent state. Uranium, under this last form can be distinguished but with difficulty by its appearance from silicium; and when crystallized, on the contrary, it has the metallic lustre and is transparent on the thinnest edges. Columbium and titanium also approach silicium by their chemical properties.*

Silica.

1699. *Oxide of Silicium*, *Silica*, or *Siliceous Earth*, is a very abundant natural product. It exists pure in rock-crystal, and nearly pure in flint. It may be obtained tolerably pure from flints by the following process:—Procure some common gun-flints, and calcine them in a crucible in a low red heat. By this treatment they will become brittle, and easily reducible to powder. Mix them, when pulverized, with three or four times their weight of carbonate of potassa, and let the mixture be fused in a strong red heat, in a crucible. The materials must bear only a small proportion to the capacity of the crucible; and the heat must at first be very moderate, and slowly increased. Even with this precaution, the mass on entering into fusion, will be apt to overflow; and must be pressed down, as it rises, by an iron rod. When this effervescence has ceased, let the heat be considerably raised, so that the materials may be in perfect fusion during half an hour, and pour the melted mass on a copper or iron dish. We shall thus obtain a compound of alkali and siliceous earth. Dissolve this in water, filter the solution, and pour it into diluted sulphuric or muriatic acid. An immediate precipitation will ensue, and as long as this continues, add fresh portions of the solution. In precipitating the alkaline solution of silica, more acid must be used than is sufficient to engage the alkali; and the alkaline liquor must be added to the acid, and not the reverse; for, in the latter case the precipitate will be glass and not silica. Let the pre-

How obtained.

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* Berzelius, *Ann. de Chim. et Phys.* xxvii. p. 337.

cipitate subside, pour off the liquor that floats above it, and wash the sediment with hot water, till it comes off tasteless. Then dry it.

Silica, obtained by this process, though pure enough for many experiments, may still contain a portion of alumina. To separate the latter earth, boil the precipitate with diluted sulphuric acid, to which a little sulphate of potassa may be added. The alumina will thus be dissolved; and the silica may be freed from the solution of alum by repeated washings with water. Even silica, however, that has been most carefully washed, still gives traces of potassa on the application of electro-chemical powers. (Davy.) H. 2. 616.

According to Prof. Brande silica may be obtained of sufficient purity for most purposes by heating rock crystal to redness, quenching it in water, and then reducing it to fine powder.

Properties.

1700. Silica is white; its specific gravity is 2,66. It fuses at a very high temperature. In its ordinary state it is insoluble in water; but it dissolves in very minute portions in that fluid, when recently precipitated in the form of gelatinous hydrate; and in the same state it dissolves sparingly in the acids. It readily unites with the fixed alkalies, and forms *glass;* or, if the alkali be in excess, a liquid solution of the earth may be obtained (*liquor silicum,*) from which it is precipitated in the state of a *gelatinous hydrate* by acids. This alkaline solution, after having been kept for several years, has formed small crystals of silica. It sometimes forms a deposit much like calcedony, and as hard.*

1701. In consequence of its possessing a stronger affinity for alkalies and earths than for acids, as well as from its other habitudes, silica has been thought to present a closer analogy with acids than with earths; but on the other hand it is deficient in some of the characters which have hitherto been deemed essential to acidity. H. 2. 618.

Glass.

1702. *Glass* is essentially a compound of silica with fixed alkali, a variety of other substances being occasionally added for particular purposes, among which oxide of lead is perhaps the most important. *Bottle glass* is obtained from a mixture of alkali and common sand, but *flint glass* is prepared from a very pure siliceous sand, a little of the oxide of lead and of manganese, being added to aid the vitrification, and prevent the green tint which is produced when any oxide of iron is present. The art of colouring glass and of making *artificial gems* is of an old date, and effected by metallic oxides.†

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* See Thomson, *First Prin.* i. 194.

† The metals employed as colouring materials are: 1. Gold. The purple of Cassius imparts a fine ruby tint. 2. Silver. Oxide or phosphate of silver gives a yellow colour. 3. Iron. The oxides of iron produce green, yellow, and brown, depending upon the state of oxidizement and quantity. 4. Copper. The oxides of copper give a rich green; they also produce a red when mixed with a small proportion of tartar, which tends partially to reduce the oxide. 5 Antimony imparts a rich yellow. 6. Manganese. The black oxide of this metal, in large quantities, forms a black glass; in smaller

Annealing.

1703. Glass vessels must be cooled very slowly, otherwise they become very brittle, and this process is termed the *annealing* of glass. When glass is properly prepared, very few chemical agents have any action on it. Fluoric acid, however, dissolves it readily, from the powerful affinity which it has for silica. The alkaline metals appear to decompose glass, combining with the oxygen of the potassa or silica ; and Sir H. Davy found that the oxide of lead, which fine glass contains, is acted on by muriatic acid at a high temperature, chloride of lead and water being formed.*

Silica abundant in nature.

1704. Silica is a very abundant product of nature. It constitutes a principal ingredient of several rocks, that form extensive mountain masses ; it composes a large proportion of the sand found in the beds of rivers, and on the sea shore, and enters largely into several minerals, as quartz, calcedony, flint, opal, &c. It constitutes an essential ingredient of fertile soils, and renders them porous and open to the transmission of moisture. H.

Silicated fluoric acid.

1705. The only acid body which acts energetically upon silica is the hydrofluoric acid. (982) The result of this action is a gaseous compound, which has been called *silicated fluoric acid*, or *fluo-silicic acid ;* it is probably a compound of silicium and fluorine.

How obtained.

1706. To obtain this gaseous compound, three parts of fluor spar, and one of silica finely powdered, are mixed in a retort with an equal weight of sulphuric acid. Or finely powdered fluor spar may be mixed with half its weight of pulverized glass and an equal weight of strong sulphuric acid ; a gentle heat is applied, and the gas evolved is to be collected over mercury.

Properties.

1707. Silicated fluoric acid is a colourless gas; its odour is acrid, much resembling muriatic acid ; its taste very sour; its specific gravity 3,574† compared with air; 100 cubic inches weigh 110,78 grains,‡ so that its specific gravity to hydrogen is 49,2. It extinguishes burning bodies. It produces white fumes when in contact with damp air; and when exposed to water, two compounds of silica with fluoric acid are formed; the one *acid*, and dissolved in the water; the other containing excess of silica, and insoluble. The dry compound contains 62 per cent. of silica ; the aqueous solution only retains 55 per cent. Water dissolves 260 times its bulk of this gas.

1708. When one volume of silicated fluoric acid is mixed with two of ammonia, a total condensation ensues, and a dry *silicofluate of ammonia* results.

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quantities, various shades of purple. 7. Cobalt, in the state of oxide, gives beautiful blues of various shades ; and with the yellow of antimony or lead it produces green. 8. Chrome produces fine greens and reds, depending upon the state of oxidizement.

The following are the best authorities upon the subject of coloured glasses and artificial gems :— Neri, *Art de la Verrerie.* Kunckel. Fontaineau, *Encyclopedie Methodique. Annales de Chim. et Phys.* xiv. 57. Aikin's *Dictionary*, Art. Glass.

* *White Enamel* is merely glass, rendered more or less milky or opaque by the addition of oxide of tin : it forms the basis of the coloured enamels, which are tinged with the metallic oxides.

† 3,6111, T.

‡ 110,1385, T.

1709. Potassium when heated in this gas, burns and produces a brown compound, which when dissolved in water, affords *hydrofluate of potassa.*

1710. It appears from the experiments of Mr J. F. Daniell, that silicium exists in some of the varieties of cast-iron:[*] and an alloy containing it has been formed by M. M. Stromeyer and Berzelius,[†] by exposing a mixture of pure iron, silica and charcoal, to an intense heat.

SECTION XXXVIII. *Aluminum.*

Aluminous minerals.

Aluminum.

1711. THE earth alumina constitutes some of the hardest gems, such as the sapphire and ruby; and combined with water, it gives a peculiar softness and plasticity to some earthy compounds, such as the different kinds of clay.—The experiments of Sir H. Davy afford a strong presumption that alumina is a metallic oxide; but its base, *aluminum*, has not been yet obtained in such a state as to make its properties an object of investigation. Yet alloys have been formed which give sufficient evidence of its existence, and the presence of oxygen in alumina is proved, by its changing potassium into potassa, when ignited with that metal. H. 2. 602.[‡]

Alumina, how obtained.

1712. To obtain pure alumina we dissolve alum in 20 times its weight of water, and add to it a little of the solution of carbonate of soda, to throw down any iron which may be present. We then drop the supernatant liquid into a quantity of the water of ammonia, taking care not to add so much of the aluminous solution as will saturate the ammonia. The volatile alkali unites with the sulphuric acid of the alum, and the earthy basis of the latter is separated in a white spongy precipitate. This must be thrown on a filter, washed by repeated affusions of water, and then dried. Or if an alum, made with ammonia instead of potassa, as is the case with some French alums, can be got, simple ignition dissipates its acid and alkaline constituents, leaving pure alumina. U. 147.[§]

Properties.

1713. Alumina is destitute of taste and smell. When moistened with water, it forms a cohesive and ductile mass, susceptible of being kneaded into a regular form. It is not soluble in water; but retains a considerable quantity, and is, indeed, a hydrate, containing, when dried at the temperature of the atmosphere, almost half its weight of water. Even after ignition, alumina has such an affinity for moisture, that it can hardly be placed on the scale, without acquiring weight. Berzelius found, that 100 parts of alumina, after being ignited gained 15¼ from a dry atmosphere, and 33 from a humid one. For full saturation, 100 grains of alumina, he ascertained, require 54 of water.[*] It does not affect vegetable colours. It is dissolved by the liquid fixed alkalies, and is precipitated by acids unchanged. In ammonia it is very sparingly soluble. It is not soluble in alkaline carbonates.

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[*] Journal of Science and the Arts, Vol. ii.

[†] Gilbert's *Annalen*, xxxviii.

[‡] There can be little doubt of the existence of silicium and aluminum, as well as of calcium, and probably magnesium, in some of the varieties of cast-iron and steel. By fusing highly carburetted steel with alumina, a peculiar alloy results, which is white, granular, and brittle, and which yields on analysis 6,4 per cent. alumina. On fusing 67 parts of this alloy with 500 of steel, a compound is obtained, which possesses all the characters of the best Bombay wootz (1140), and like it, when its surface is polished and washed over with dilute sulphuric acid, exhibits the striated appearance called *damask*, for which the celebrated sabres of Damascus are remarkable, and which renders it probable that they also are made of wootz. (*Quarterly Journal of Science and Arts*, ix.) Many of the varieties of cast-iron afford lime and silica when dissolved in acids, and it is highly probable that those substances as well as the alumina in the wootz, exist combined with the iron in their deoxidized or metallic state. B.

[§] Gay-Lussac, *Ann. de Chim. et Phys.* v. 101.

Baryta and strontia combine with alumina, both by fusion, and in the humid way. In the first case the result is a greenish or bluish coloured mass. In the second two compounds are formed. The first containing an excess of alumina, is in the state of an insoluble powder; the other, having an excess of the alkaline earth, remains in solution.

Effect of heat.

1714. Alumina has the property of shrinking considerably in bulk, when exposed to heat. On this property is founded the *pyrometer* of Mr Wedgwood which measures high degrees of heat, by the amount of the contraction of regularly shaped pieces of china clay.[†] This instrument, however, is not an accurate measurer of heat, since the contraction of clay is influenced not merely by the degree of heat to which it is exposed, but by the mode of its application. H.

Equivalent number.

1715. From indirect experiments, Sir H. Davy derived 24 as the number representing alumina, from which, deducting one atom of oxygen = 8, we obtain 16 for the equivalent of aluminum. The number for the equivalent of alumina, deduced by Gay-Lussac,[‡] is 21,611, oxygen being 10; = 17,28, when hydrogen is taken as the decimal unit. Dr Thomson[§] from recent experiments, concludes it to be 2,25, oxygen being 1; = 18 when hydrogen is made unity. The former determination would reduce the atom of aluminum to 9,28, and Dr Thomson's to 10, the atom of oxygen being considered as 8. Mr R. Phillips is of opinion that the atom of alumina is correctly expressed by 27, and Mr Brande[||] fixes it at 26.

Muriate of alumina.

1716. *Muriate of Alumina* may be formed by dissolving fresh prepared alumina in muriatic acid, but the acid is always in excess. It is scarcely possible to obtain this salt in crystals, for by evaporation it becomes a thick jelly. It is extremely soluble in water, and when dried deliquiates. At a high temperature it abandons its acid.

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[*] Ann de Chim. lxxxii. 14.

[†] For a description of this instrument see *Henry's Chemistry*, ii. 604

[‡] Ann. de Chim. et Phys. xvi. 36.

[§] Ann. of Philos. N. S. iii. 168, and T. First Prin. 1. 310.

[||] Quart. Jour. xiv. 50.

Nitrate.

1717. *Nitrate of Alumina* may be formed in the same manner as the last mentioned compound. The solution which is always acid, crystallizes in thin ductile plates. The crystals are extremely soluble, and deliquescent. At a high temperature they are decomposed. Potassa throws down alumina from the solution, but if added in excess, re-dissolves the precipitate.* H. 2. 606.

Alum.

1718. One of the saline combinations of alumina is of important use in the arts, namely, *alum*;† a *triple sulphate of alumina and potassa.* This salt is usually prepared by roasting and lixiviating certain clays containing pyrites; to the leys, a certain quantity of potassa is added, and the triple salt is obtained by crystallization.‡

Alum has a sweetish astringent taste. It dissolves in 5 parts of water at 60°, and the solution reddens vegetable blues. It furnishes octoëdral crystals. In its crystalline form it consists, according to some recent experiments made by Mr R. Phillips, of

Compositio

Sulphate of alumina	123,00
Bi-sulphate of potassa	119,32
Water	187,00
	429,32

Mr Phillips adopts the number 27 as the representative of alumina, and considers alum as a compound of 2 proportionals of sulphate of alumina, 1 of bi-sulphate of potassa, and 22 of water.

Dr Thomson does not admit that bi-sulphate of potassa exists in alum, and contends that it is constituted of 1 atom of sulphate of potassa, 3 atoms of sulphate of alumina, and 25 atoms of water.§

Alumen ustum.

1719. When alum is exposed to an intense heat, it loses water, and a portion of acid; but the whole of the acid cannot be expelled. It becomes light and spongy; and in this state is called in the *Pharmacopœia*, *Alumen ustum*, or *exsiccatum.*

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* For a more particular account of the nitrates of alumina, see Thomson's *First Principles*, Vol. 2.

† When alumina and sulphuric acid form a triple salt with some other salifiable base instead of potassa, the compound is also called alum, but the name of that base is also prefixed to it. Thus ammoniacal alum is the sulphate of alumina and ammonia; soda alum is the sulphate of alumina and soda.

‡ Sulphate of alumina will not crystallize; but if a solution of sulphate of potassa be added to solution of sulphate of alumina, small octoëdral crystals of alum are precipitated.

§ *First Princip.* i. 307.—Considerable differences exist in the statements which have been given by different analysists, of the composition of alum, as will appear from the following table:

100 parts contain	Acid.	Alumina.	Potassa.	Water.
According to Vauquelin	30,52	10,50	10,40	48,58
——— Dalton	33,	12,	9,	46,
——— R. Phillips	34,94	11,18	10,33	43,56
——— Berzelius	34,23	10.86	9,81	45,
Do. corrected by Thomson	33,82	10,86	9.90	46,
——— Dr Thomson	32,85	11,99	9,85	46,21 H.

If alum contain excess of potassa it forms cubic crystals, and is known under the name of cubic alum.

1720. When alum is ignited with charcoal, a spontaneously inflammable compound results, which has long been known under the name of *Homberg's pyrophorus.* The potassa appears to be decomposed in this process, along with the acid of the alum, and pyrophorus is probably a compound of sulphur, charcoal, and potassium, with alumina.

Pyrophorus.

Pyrophorus may be prepared by the following process. Mix equal parts of honey, or of brown sugar with powdered alum, in an iron ladle, melt the mixture over a fire, and keep it stirred till dry: reduce the dry mass to powder, add a few grains of potassa, and introduce it into a common phial coated with clay, and placed in a crucible of sand. Give the whole a red heat, and when a blue flame appears at the neck of the phial allow it to burn about five minutes, then remove it from the fire; stop the phial, and allow it to cool, taking care that air cannot enter it.

Dr Hare's process.

Dr Hare recommends the following method, which affords a pyrophorus that rarely fails. Take three parts of lampblack, four of calcined alum, and eight of pearlashes; mix them thoroughly, and heat them in an iron tube to a bright cherry red for one hour. On removal from the fire the tube should be carefully stopped. When well prepared and poured out upon a glass plate and especially when breathed upon, the pyrophorus kindles with a series of small explosions.* The inflammability of this compound arises from the presence of potassium. (See *Alloys of Potassium*, p. 242.)

Uses.

1721. Alum is of extensive use in the arts, more especially in dyeing and calico-printing, in consequence of the attraction which alumina has for the colouring matter.

Soda alum.

1722. A *triple sulphate of alumina and soda* is described in the *Quarterly Journal of Science and the Arts*, (viii. 386.) in the form of irregular efflorescent octoëdra: it appears to contain 2 proportionals of sulphate of alumina, 1 proportional bi-sulphate of soda, and 28 proportionals water.†

1723. Magnesia, also, it appears, is capable of furnishing a base to alum; but like the last species it has not been applied to any useful purpose.

Neutral sulphate.

1724. A neutral sulphate of alumina was obtained by Berzelius by the following process. He decomposed alum by ammonia; washed the precipitate, and re-dissolved it in sulphuric acid. To the liquor, after evaporation, he added alcohol, which threw down a sulphate nearly neutral, and rendered perfectly so, by being washed with farther portions. Gay-Lussac has also given the following process, for preparing a neutral sulphate of alumina. On alum with base of ammonia, boil nitro-muriatic acid, till all the ammonia is destroyed, and evaporate to dryness to expel all the nitric and muriatic acids. The ammonia is decomposed by the chlorine, which results from the mutual action of those two acids, and the alumina remains in combination with sulphuric acid only. The saturated solution of this salt in water is an excellent test to discover potassa; for a drop or two, added to a solution of that alkali, or of any of its salts, immediately causes a precipitation of alum.* It is most probably constituted of 1 atom of acid + 1 atom of base. H. 2. 609.

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* The pyrophorus obtained by Dr Hare's process should be removed from the tube with great caution, as it has been found to explode violently on the introduction of a rod for the purpose of loosening it.—Silliman in *Amer. Jour. of Science*, x. 367.

† *Ammoniacal Alum* has been examined by Riffault (*Ann. de Chim. et Phys.* ix. 106) who found it to consist of 1 atom sulphate of ammonia, 3 atoms sulphate of alumina and 24 atoms water.

Section XXXIX. *Zirconium.*

1725. The base of zirconia, or *zirconium*, was investigated by Sir H. Davy in the same manner as the bases of other earths. When potassium was brought into contact with zirconia ignited to whiteness, potassa was formed, and dark particles of a metallic aspect were diffused through the alkali. Examined by Davy.

Berzelius has more lately obtained zirconium by a process analogous to that by which he obtained silicium. (1685)† Obtained by Berzelius.

1726. Zirconium, according to Berzelius, is as dark coloured as carbon, it is not oxidized by water. Muriatic acid does not act upon it, but nitro-muriatic and fluoric acids dissolve it; the action of the latter being attended with the disengagement of hydrogen. It burns at a moderately elevated temperature, with great brilliancy. It combines with sulphur and forms a brown compound, insoluble in muriatic acid and in alkalies. The sulphuret burns with the production of sulphurous acid gas and zirconia.‡ Characters.

1727. The earth *zircon*, or the *oxide of zirconium*, is found in the zircon or *jargon* of Ceylon; in the *hyacinth* and in the *eudialyte* from Greenland.

1728. Zirconia is obtained by the following process: Reduce the stone to a fine powder, having previously heated it to redness, and quenched it in water. Mix the powder with nine times its weight of pure potassa, and gradually project it into a red-hot silver crucible, and keep it in perfect fusion for two hours. When the crucible has cooled, reduce the mass to a fine powder, and boil it in distilled water. Boil the undissolved residue in muriatic acid; filter, and evaporate to dryness; re-dissolve the dry mass in distilled water, and precipitate by carbonate of soda. The carbonate of zirconia which falls may be decomposed by heat. Mode of obtaining zirconia.

The following method of obtaining pure zirconia is recommended by M. M. Dubois and Silveira.‡ Powder the zircons very fine, mix them with two parts of pure potassa, and heat them red-hot in a silver crucible for an hour. Treat the substance obtained with distilled water, pour it on a filter, and wash the insoluble part well; it will be a compound of zirconia, silica, potassa, and oxide of iron. Dissolve it in muriatic acid, and evaporate to dryness, to separate the silica. Re-dissolve the muriates of zirconia and iron in water; and to separate the zirconia which adheres to the silica, wash it with weak muriatic acid, and add it to the solution. Filter the fluid and precipitate the zirconia and iron by pure ammonia; wash the precipitates well, and then treat the hydrates with oxalic acid, boiling them well together, that the acid may act on the iron, retaining it in solution whilst an insoluble oxalate of zirconia is formed. It is then to be filtered, and the oxalate washed, until no iron can be detected in the water that passes. The earthy oxalate is, when dry, of an opaline colour; after being well washed, it is to be decomposed by heat in a platinum crucible. Thus obtained, the zirconia is perfectly pure, but is not affected by acids. It must be re-acted on by potassa as before, and then washed until the alkali is removed. Afterwards dissolve it in muriatic acid, and precipitate by ammonia. The hydrate thrown down, when well washed, is perfectly pure, and easily soluble in acids.

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* Ann. de Chim. et Phys. vi. 201.

† Ann. de Chim. et Phys. xxvi. 40.

‡ Ann. de Chim et Phys. xiv. 110.

Properties.

1729. Zirconia is in the form of a fine white powder, which, when rubbed between the fingers, has somewhat of the harsh feel of silica. It is entirely destitute of taste or smell. Its specific gravity exceeds 4. It is insoluble in water, yet appears to have some affinity for that fluid, retaining when slowly dried after precipitation, one third its weight, and appearing like gum arabic.

It is insoluble in pure liquid alkalies; nor does it combine with them by fusion, but it is soluble in alkaline carbonates.

Effect of heat,

1730. Exposed to a strong heat, zirconia fuses, assumes a light grey colour; and such hardness, on cooling, as to strike fire with steel and to scratch even rock crystal.

— of acids.

1731. It dissolves readily in acids. Its solution in muriatic acid, when sufficiently heated, becomes milk white, and runs in some measure into a jelly, especially if concentrated to a certain point by evaporation.

Precipitants.

1732. From the muriatic solution of zirconia, oxalic acid throws down a white precipitate, which is re-dissolved by an excess of the acid.

It is precipitated from its acid solutions, by the neutral succinates and benzoates, in copious white bulky flocks, which are again readily dissolved by an excess of succinic acid. It is also thrown down from its solutions by tartaric acid, malic acid, and tartrate of potassa.

From a sufficiently neutral solution of zirconia, ferrocyanate of potassa throws down a greenish blue precipitate, which, on adding muriatic acid, becomes more blue, but after some time changes into a celadon-green.

Hydrosulphuret of ammonia produces, in the muriatic solution of zirconia, a dark olive or blackish-green precipitate in very loose flocks. This precipitate may be washed with water without changing colour; but when exposed to sunshine, it becomes white.

Resembles oxide of titanium.

1733. Professor Pfaff has remarked, that in most of their properties there is a striking resemblance between zirconia and oxide of titanium. The only re-agent, which acts in a strikingly different manner upon solutions of oxide of titanium and zirconia, is tincture of galls, which, from the common solution of oxide of titanium, throws down a reddish brown precipitate, whereas from solution of zirconia, it occasions a deposition of yellow flocks.[*] H. 2. 613.

Section XL. *Glucinum.*

1734. We have no knowledge of the base of glucina. When obtained, its proper denomination will be *glucinum*. The general fact of its existence is proved by igniting glucina with potassium, which is thus changed into potassa.

Properties.

1735. The earth *glucina* was discovered by Vauquelin in the beryl, euclase and the emerald. It is white and insipid; its specific gravity = 2,97. It dissolves in caustic potassa and soda, and thus resembles alumina, but differs from yttria. Again it differs from alumina, but resembles yttria in being soluble in carbonate of ammonia; it is much more soluble in this solution than yttria. With the acids it forms saline compounds of a sweetish astringent taste.

Method of obtaining glucina.

1736. To obtain glucina from either of these minerals proceed as follows:—Reduce it to a fine powder, and fuse it with thrice its weight of potassa; dissolve in a dilute muriatic acid; evaporate to dryness; re-dissolve in water, and precipitate by carbonate of potassa. Dissolve this precipitate in sulphuric acid and add a little sulphate of potassa, and on evaporation crystals of alum will be obtained. These being separated, add excess of carbonate of ammonia to the residuary liquor, which will retain glucina in solution, but the alumina will be precipitated; filter, and evaporate to dryness, and apply a red heat; glucina remains.

Glucina is inferred from analogy to be a compound of 1 atom glucinum + 1 atom of oxygen. T.

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[*] Ann. of Philos. xiii. 83.

Section XLI. *Yttrium.*

Discovery.

1737. In 1794 Professor Gadolin discovered a new earth in a mineral from the quarry of Ytterby in Sweden, to which Eckeberg, in 1797, gave the name of *Yttria*. The mineral has since been termed *Gadolinite*. Oxide of yttrium, or yttria, may be obtained by the following process: Pulverise the mineral and boil in repeated portions of nitro-muriatic acid; evaporate nearly to dryness, dilute with water, and filter; evaporate to dryness, ignite the residue for some hours in a close vessel, re-dissolve, and filter. To this solution add ammonia, which throws down yttria and oxide of cerium; heat the precipitate red-hot, dissolve it in nitric acid, and evaporate to dryness; dilute with 150 parts of water, and put crystals of sulphate of potassa into the liquid. The crystals gradually dissolve, and, after some hours, a white precipitate appears of oxide of cerium, the whole of which must be separated by a repetition of the process. The liquor is then to be filtered, and the addition of pure ammonia forms a precipitate of yttria, which is to be washed and heated red-hot.*

How to obtain yttria.

Properties.

1738. Yttria is insipid, white, and without action on vegetable colours. It is insoluble in water, but very retentive of it. Insoluble in pure alkalies, but readily soluble in carbonated alkalies. It forms salts which have a sweetish austere taste, and which have been little examined. From indirect experiments it probably contains 25 per cent. oxygen. B.

Precipitants.

1739. It is precipitated from its solutions by the oxalic acid, and by oxalate of ammonia, in a state resembling fresh precipitated muriate of silver. Prussiate of potassa throws it down in small white grains passing in a short time to pearl grey; phosphate of soda in a white gelatinous form; and infusion of galls in brown flocculi.

Yttria which has been a long time exposed to the action of fire, gives out chlorine gas, when dissolved in common muriatic acid; thus manifesting one property of a metallic oxide.† H. 2. 602.

Phosphate.

1740. *Phosphate of Yttria* has been lately discovered in Norway, in crystals of a yellowish brown colour, which, according to the analysis of Berzelius, consist of

Yttria	62,58
Phosphoric acid, with a little fluoric acid .	33,49
Phosphate of iron, with excess of base . .	3,93‡

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* Berzelius in Thomson's *Chemistry*, Vol. i. p. 357.

† Nicholson's *Journal*, xviii. 77.

‡ Brewster's *Journal*, iii. 329.

SECTION XLII. *Thorinum.*

Discovery.

1741. IN examining some minerals from the neighbourhood of Fahlun in Sweden, Prof. Berzelius found in them a new earth, which he had also extracted, in the year 1815, from the mineral *gadolinite.* In these minerals this earth was combined with the fluate of cerium and yttria.

Of the metallic base of this earth nothing is known, but from analogy it is inferred to be constituted of such a base united to oxygen: and to this supposed base the name *Thorinum* was given, from Thor, a Scandinavian Deity.

Method of obtaining thorina.

1742. Thorina was obtained by the following process. The pulverized mineral was first treated with concentrated sulphuric acid, which decomposed the greater part of it, and expelled the fluoric acid. From this solution, sulphate of potassa precipitated the oxide of cerium, and caustic ammonia afterwards occasioned a farther precipitate. This, dissolved by long digestion in muriatic acid, consisted of the muriates of yttria and of the new earth. It was evaporated to dryness, in order to expel the excess of acid, and water poured over it to dissolve the muriate of yttria. The residue was subjected to the action of muriatic acid, and the solution accurately saturated by caustic ammonia. On adding water, and applying a boiling heat, a white gelatinous precipitate fell, which was collected on a filter. The liquor, that passed through the filter, was again saturated with pure ammonia, and heated to ebullition, which occasioned a fresh precipitation of the same earth. This, when washed and gently dried, is the substance in question.

Properties.

1743. This earth, when dried, is perfectly white; it absorbs carbonic acid, and dissolves with effervescence in acids. After calcination, its white colour remains unimpaired; but if the heat has been strong, it is rendered less easily soluble in acids. The neutral solutions of it have a purely astringent taste, which is neither sweet, nor saline, nor bitter, nor metallic, a property in which it differs from all the earths except zirconia.

1744. When dissolved in a slight excess of sulphuric acid, and subjected to evaporation, it yields transparent crystals, which are not altered by exposure to the air, and have a sweet astringent taste.

Precipitants.

1745. It dissolves readily in nitric and muriatic acids, but does not afford crystallizable salts. When precipitated by pure alkalies, it absorbs carbonic acid from the air with avidity; and he alkaline carbonates throw it down, in combination with the whole of their carbonic acid. It is precipitated by the oxalate, artrate, and benzoate of ammonia. Succinate of ammonia occaions a precipitate, which is immediately re-dissolved; and erro-prussiate of potassa throws down a white precipitate, which is soluble in muriatic acid.

1746. It is not soluble, even when fresh precipitated and at a boiling temperature, by the pure alkalies. The alkaline carbonates dissolve it, but much more sparingly than any other earth, on which they are capable of acting.

1747. It is not reducible, when strongly heated in contact with charcoal. Before the blow-pipe, it cannot be brought into fusion. With borax or phosphate of soda, it fuses into a transparent glass, but is infusible with soda.

Distinguishing characters.

1748. Thorina differs from the other earths in the following properties: From *alumina* and *glucina*, by its insolubility in liquid potassa: from *yttria*, by its solutions being purely astringent to the taste, without any sweetness, and by the property of being precipitated at a boiling heat, except when prevented by too great an excess of acid. It differs from *zirconia* in the following respects: 1st, Because after being ignited, it is still soluble in acids. 2d, It is not precipitated by sulphate of potassa, which throws down zirconia, even from solutions containing a considerable excess of acid. 3d, Thorina is precipitated by oxalate of ammonia, which is not the case with zirconia. 4th, Its combination with sulphuric acid crystallizes readily, while sulphate of zirconia forms, when pure and dried, a gelatinous mass, without any trace of crystallization. H. 2. 610.[*]

CHAPTER V.

OF THE ANALYSIS OF MINERALS.[†]

Object of chemical analysis.

1749. CHEMICAL analysis consists of a great variety of operations, performed for the purpose of separating the component parts of bodies. In these operations the most extensive knowledge of such properties of bodies as are already discovered must be applied, in order to produce simplicity of effect, and certainty in the results. Chemical analysis can hardly be executed with success, by one who is not in possession of a considerable number of simple substances in a state of great purity, many of which, from their effects are called *reagents*.

As most of the improvements in the science of chemistry consist in bringing the art of analysis nearer to perfection, it is not easy to give any other rule to the learner than the general one of consulting and remarking the processes of the best chemists, such as Scheele, Bergman, Berthollet, Kirwan, Vauquelin, and Berzelius. The bodies which present themselves more frequently for examination than others, are minerals and mineral waters. In the examination of the former, it was the habit of the earlier chemists to avail themselves of the action of fire, with very few humid processes, which are such as might be performed in the usual temperature of the atmosphere. Modern chemists have improved the process by fire, by a very extensive use of the blow-pipe ;* and have succeeded in determining the component parts of minerals to great accuracy in the humid way.

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[*] There has lately appeared in some of the Scientific Journals an extract of a letter from Berzelius in which thorina is said to be a phosphate of yttria with an excess of base; but as no detailed account of experiments on this subject has been met with, the brief notice alluded to was not deemed sufficient authority for excluding thorinum from the metals.

[†] From Ure's *Dictionary*, p. 161—4.

Several authors have written on the examination of earths and stones.†

Preliminary operations.

1750. The first step in the examination of consistent earths or stones is somewhat different from that of such as are pulverulent. Their specific gravity should first be examined ; also, their hardness, whether they will strike fire with steel, or can be scratched by the nail, or only by crystal or stones of a still greater hardness; also their texture, perviousness to light, and whether they be manifestly homogeneous or compound species, &c.

2d, In some cases, we should try whether they imbibe water, or whether water can extract any thing from them by ebullition or digestion.

3d, Whether they be soluble in, or effervesce with acids, before or after pulverization ; or whether decomposable by boiling in a strong solution of potassa, &c. as gypsums and ponderous spars are.

4th, Whether they detonate with nitre.

5th, Whether they yield the fluoric acid by distillation with sulphuric acid, or ammonia by distilling them with potassa.

6th, Whether they be fusible *per se* with a blow-pipe, and how they are affected by soda, borax, and microcosmic salt; and whether they decrepitate when gradually heated.

7th, Stones that melt *per se* with the blow-pipe are certainly compound, and contain at least three species of earth, of which the calcareous is probably one ; and if they give fire with steel, the siliceous is probably another.

1751. The general process prescribed by the celebrated Vauquelin, in the 30th volume of the Annales de Chimie, is the clearest which has yet been offered to the chemical student.

Reduction to powder.

If the mineral be very hard, it is to be ignited in a covered crucible of platinum, and then plunged into cold water, to render it brittle and easily pulverizable. The weight should be noted before and after this operation, in order to see if any volatile matter has been emitted. For the purpose of reducing stones to an impalpable powder, little mortars of highly hardened steel are now made, consisting of a cylindrical case and pestle. (fig. 123.) A mortar of agate is also used for subsequent levigation. About ten grains of the mineral should be treated at once; and after the whole 100 grains have been reduced in succession to an impalpable powder, they should be weighed to find what increase may have been derived from the substance of the agate. This addition may be regarded as silica.

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* See Children's translation of *Berzelius on the Blow-pipe*.

† See Thenard's *Traite de Chim*. Tom. v.

Most usual earths.

1752. Of the primary earths, only four are usually met with in minerals, viz. silica, alumina, magnesia, and lime, associated with some metallic oxides, which are commonly iron, manganese, nickel, copper, and chromium.

Fusion, how effected.

1753. If neither acid nor alkali be expected to be present, the mineral is mixed in a silver crucible, with thrice its weight of pure potassa and a little water. Heat is gradually applied to the covered crucible, and is finally raised to redness; at which temperature it ought to be maintained for an hour. If the mass, on inspection, be a perfect glass, silica may be regarded as the chief constituent of the stone; but if the vitrification be very imperfect, and the bulk much increased, alumina may be supposed to predominate. A brownish or dull green colour indicates the presence of iron; a bright grass-green, which is imparted to water, that of manganese; and from a greenish-yellow, chromium may be expected. The crucible, still a little hot, being first wiped, is put into a capsule of porcelain or platinum; when warm distilled water is poured upon the alkaline earthy mass, to detach it from the crucible. Having transferred the whole of it into the capsule, muriatic acid is poured on, and a gentle heat applied, if necessary, to accomplish its solution. If the liquid be of an orange-red colour, we infer the presence of iron; if of a golden-yellow, that of chromium; and if of a purplish-red, that of manganese. The solution is next to be evaporated to dryness, on a sand bath, or over a lamp, taking care so to regulate the heat that no particles be thrown out. Towards the end of the evaporation, it assumes a gelatinous consistence. At this period it must be stirred frequently with a platinum spatula or glass rod, to promote the disengagement of the muriatic acid gas. After this, the heat may be raised to fully 212° F. for a few minutes. Hot water is now to be poured on in considerable abundance, which dissolves every thing except the silica. By filtration, this earth is separated from the liquid; and being edulcorated with hot water, it is then dried, ignited, and weighed. It constitutes a fine white powder, insoluble in acids, and feeling gritty between the teeth. If it be coloured, a little dilute muriatic acid must be digested on it, to remove the adhering metallic particles, which must be added to the first solution. This must now be reduced by evaporation to the bulk of half a pint. Carbonate of potassa being then added, till it indicates alkaline excess, the liquid must be made to boil. A copious precipitation of the earth and oxides is thus produced. The whole is thrown on a filter, and after it is so drained as to assume a semi-

Inferences from the appearance of the fused mass.

Solution.

Separation of silica.

solid consistence, it is removed by a platinum blade, and boiled in a capsule for some time, with solution of pure potassa. Alumina and glucina are thus dissolved, while the other earths and the metallic oxides remain.

— of alumina

1754. This alkalino-earthy solution, separated from the rest by filtration, is to be treated with an excess of muriatic acid; after which carbonate of ammonia being added also in excess, the alumina is thrown down, while the glucina continues dissolved. The first earth, separated by filtration, washed, dried, and ignited, gives the quantity of alumina. The nature of this may be further demonstrated, by treating it with dilute sulphuric acid, and sulphate of potassa, both in equivalent quantities, when the whole will be converted into alum. (See ALUM.) The filtered liquid will deposit its glucina, on dissipating the ammonia, by ebullition. It is to be separated by filtration, to be washed, ignited, and weighed.

and glucina.

— of magnesia and metallic oxides.

1755. The matter undissolved by the digestion of the liquid potassa, may consist of lime, magnesia, and metallic oxides. Dilute sulphuric acid must be digested on it for some time. The solution is to be evaporated to dryness, and heated to expel the excess of acid. The saline solid matter being now diffused in a moderate quantity of water, the sulphate of magnesia will be dissolved, and, along with the metallic sulphates, may be separated from the sulphate of lime by the filter. The latter being washed with a little water, dried, ignited, and weighed, gives, by the scale of equivalents, the quantity of lime in the mineral. The magnesian and metallic solution being diluted with a large quantity of water, is to be treated with bicarbonate of potassa, which will precipitate the nickel, iron, and chromium, but retain the magnesia and manganese, by the excess of carbonic acid. Hydrosulphuret of potassa will throw down the manganese, from the magnesian solution. The addition of pure potassa, aided by gentle ebullition, will then precipitate the magnesia. The oxide of manganese may be freed from the sulphuretted hydrogen, by ustulation.

— iron and nickel.

1756. The mingled metallic oxides must be digested with abundance of nitric acid, to acidify the chromium. The liquid is next treated with potassa, which forms a soluble chromate, while it throws down the iron and nickel. The chromic acid may be separated from the potassa by muriatic acid, and digestion with heat, washed, dried till it becomes a green oxide, and weighed. The nickel is separated from the iron, by treating their solution in muriatic acid, with water and ammonia. The latter oxide which falls, may be separated by the filter, dried and weighed. By evaporating the liquid, and exposing the dry residue to a moderate heat, the ammoniacal salt will sublime, and leave the oxide of nickel behind. The whole separate weights must now be collected in one amount, and if they constitute a sum within two per cent. of the primitive weight, the analysis may be regarded as giving a satisfactory account of the composition of the mineral. But if the deficiency be considerable, then some volatile ingredient, or some alkali or alkaline salt, may be suspected.

To ascertain the presence of volatile and other substances.

1757. A portion of the mineral broken into small fragments, is to be ignited in a porcelain retort, to which a refrigerated receiver is fitted. The water, or other volatile and condensible matter, if any be present, will thus be obtained. But if no loss of weight be sustained by ignition, alkali or a volatile acid, may be looked for. The latter is usually the fluoric. It may be expelled by digestion with sulphuric acid. It is exactly characterized by its property of corroding glass.

1758. Besides this general method, some others may be used in particular cases.

To discover small portions of alumina, &c.

Thus, to discover a small proportion of alumina or magnesia in a solution of a large quantity of lime, pure ammonia may be applied, which will precipitate the alumina or magnesia (if any be present,) but not the lime. Distilled vinegar applied to the precipitate will discover whether it be alumina or magnesia.

1759. A minute portion of lime or baryta, in a solution of alumina or magnesia, may be discovered by the sulphuric acid, which precipitates the lime and baryta: the solution should be dilute, else the alumina also would be precipitated. If there be not an excess of acid, the oxalic acid is still a nicer test of lime: 100 grains of gypsum contain about 33 of lime; 100 grains of sulphate of baryta contain 66 of baryta; 100 grains of oxalate of lime contain 43,8 of lime. The insolubility of sulphate of baryta in 500 times its weight of boiling water, sufficiently distinguishes it. From these data the quantities are easily investigated.

Separation of alumina from magnesia.

1760. A minute proportion of alumina in a large quantity of magnesia may be discovered, either by precipitating the whole, and treating it with distilled vinegar; or by heating the solution nearly to ebullition, and adding more carbonate of magnesia, until the solution is perfectly neutral, which it never is when alumina is contained in it, as this requires an excess of acid to keep it in solution. By these means the alumina is precipitated in the state of embryon alum, which contains about half its weight of alumina, (or, for greater exactness, it may be decomposed by boiling it in volatile alkali.) After the precipitation the solution should be largely diluted, as the sulphate of magnesia, which remained in solution while hot, would precipitate when cold, and mix with the embryon alum.

— of magnesia from alumina.

1761. A minute portion of magnesia, in a large quantity of alumina is best separated by precipitating the whole, and treating the precipitate with distilled vinegar.

Lime and baryta.

1762. Lime and baryta are separated by precipitating both with the sulphuric acid, and evaporating the solution to a small compass, pouring off the liquor, and treating the dried precipitate with 500 times its weight of boiling water; what remains undissolved is sulphate of baryta.

Method of regulating the heat.

1763. The inconveniences of employing much heat are obvious, and Mr Lowitz informs us that they may be avoided without the least disadvantage. Over the flame of a spirit lamp, that will hold an ounce and half, and is placed in a cylindrical tin furnace, four inches high and three in diameter, with air holes, and a cover perforated to hold the crucible, he boils the stone prepared as directed above, stirring it frequently. His crucible, which, as well as the spatula, is of very fine silver, holds two ounces and a half, or three ounces. As soon as the matter is boiled dry, he pours in as much hot water as he used at first; and this he repeats two or three times more, if the refractoriness of the fossil require it. Large tough bubbles arising during the boiling, are in general a sign that the process will be attended with success. Even the sapphire, though the most refractory of all Mr Lowitz tried, was not more so in this than in the dry way.

Analysis with boracic acid.

1764. Sir H. Davy observes, that the boracic acid is very useful in analyzing stones that contain a fixed alkali; as its attraction for the different earths at the heat of ignition is considerable, and the compounds it forms with them are easily decomposed by the mineral acids dissolved in water. His process is as follows: Let 100 grains of the stone to be examined be reduced to a fine powder, mixed with 200 grains of boracic acid, and fused for about half an hour at a strong red heat in a crucible of platinum or silver. Digest the fused mass in an ounce and half of nitric acid, diluted with seven or eight times the quantity of water, till the whole is decomposed; and then evaporate the solution till it is reduced to an ounce and half, or two ounces. If the stone contained silica, it will separate in this process, and must be collected on a filter, and edulcorated with distilled water, to separate the saline matter. The fluid, mixed with all the water that has been passed through the filter, being evaporated till reduced to about half a pint, is to be saturated with carbonate of ammonia, and boiled with an excess of this salt, till all that will precipitate has fallen down. The earths and metallic oxides being separated by filtration, mix nitric acid with the clear fluid till it has a strongly sour taste, and then evaporate till the boracic acid remains free. Filter the fluid, evaporate it to dryness, and expose it to a heat of 450° F. when the nitrate of ammonia will be decomposed, and the nitrate of potassa or soda will remain in the vessel. The earths and metallic oxides that remained on the filter, may be distinguished by the common processes. The alumina may be separated by solution of potassa, the lime by sulphuric acid, and the oxide of iron by succinate of ammonia, the manganese by hydrosulphuret of potassa, and the magnesia by pure soda.

1765. Lately carbonate or nitrate of baryta, and carbonate with nitrate of lead, have been introduced into the mineral analysis with great advantage for the fluxing of stones that may contain alkaline matter.*

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* See the English translation of M. Thenard's volume on analysis.

CHAPTER VI.

OF THE ANALYSIS OF MINERAL WATERS.

SECTION I. *Of the Tests and Apparatus required in the Examination and Analysis of Mineral Waters.*

Tests and Reagents.

1766. Those who have not access to a regular laboratory will find it convenient to arrange the following tests and re-agents in the manner represented in plate vi. of this work, the larger phials should contain about 6 ounces by measure; the second size, 3 ounces; and the smallest, 1 ounce. Of these phials, the greater number should be simply stopped, and a few of them provided with an elongated stopper dipping into the fluid which they contain.

The larger phials may contain the following re-agents:

Pure sulphuric acid.
—— nitric acid.
—— muriatic acid.
Dilute sulphuric acid, 1 acid + 3 water.
—— nitric acid . . . . . . ditto.
—— muriatic acid . . . . ditto.
Solution of potassa.
—— soda.
—— ammonia.
—— carbonate of potassa.
—— carbonate of soda.
—— carbonate of ammonia.
—— oxalic acid.
—— oxalate of ammonia.
—— baryta.
—— acetate of baryta.
—— nitrate of baryta.
—— phosphate of soda.
—— sulphate of silver.
Alcohol.

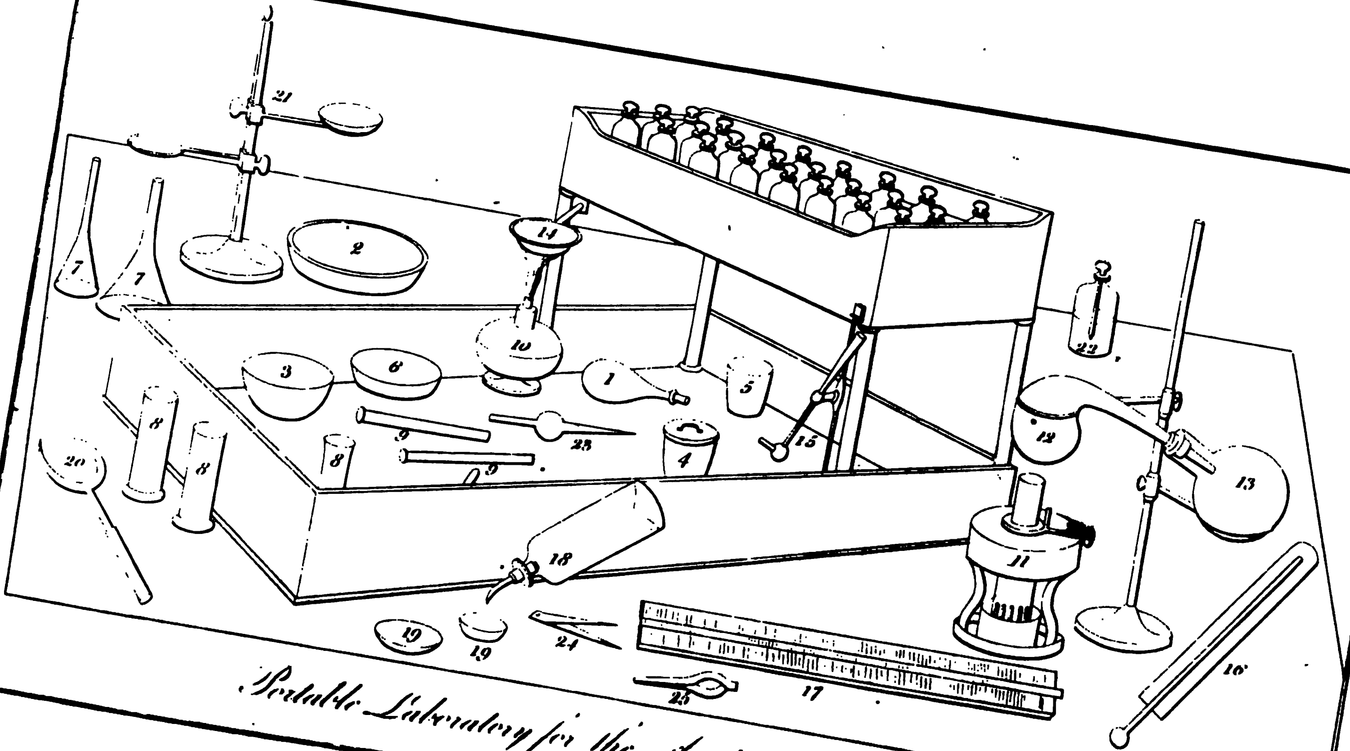
The smaller phials may contain

Tincture of galls.
Solution of iodine in alcohol.
—— nitrate of silver.
—— ferro cyanate of potassa.
—— muriate of lime.
—— hydrosulphuret of ammonia.
—— hydriodate of potassa.
—— soap in alcohol.
Phosphorus.
Sulphate of lime.
Test-papers, turmeric, litmus, violet.
Black flux.
Nitrate of ammonia.

Portable laboratory.

The tray should contain a few Florence flasks (1), Wedgwood and glass basins (2, 3), a platinum and a silver crucible (4, 5), a silver capsule (6), some funnels (7), test-glasses (8), test-

PL.VI.



Portable Laboratory for the Analysis of Mineral Waters.

tubes (9), and glass rods, filtering paper, a spirit (10), and an Argand's lamp (11), a retort (12), and receiver (13), a copper basin to serve as sand-bath (14), a blow-pipe (15), a thermometer (16), a scale of equivalents (17), a dropping-bottle (18), a few watch-glasses (19), a support for holding glasses over a lamp (20), a small brass stand with rings (21), a tube, with a bulb in the centre and a pointed extremity for drawing up small portions of liquids (23), platinum pincers (24, 25); a small but good balance, with well-adjusted weights, is also requisite, accompanied by a phial and counterpoise for taking specific gravities; and, lastly, a small mercurial trough. There should also be a plentiful supply of distilled water, a portion of which should be contained in a dropping bottle.

SECTION II. *Examination of Mineral Waters by Tests.*

Division of mineral waters.

1767. i. THE term *mineral water* is applied to those natural spring waters which contain so large a proportion of foreign matter as to render them unfit for common domestic use, and to confer upon them a sensible flavour, and specific action upon the animal frame. Their temperature is liable to considerable variation, and is sometimes their principal character, as is the case with the waters of Bath and Buxton; but they are generally so far impregnated with acid or saline bodies, as to derive from them their peculiarities, and in this respect may conveniently be arranged under the heads of *carbonated, sulphureous, saline* and *chalybeate* waters. The mere taste of the water enables us to determine to which of these subdivisions it probably belongs.

Specific gravity.

ii. In examining a mineral water, it is of importance to ascertain its specific gravity, which gives us some insight into the proportion of its saline ingredients, its specific weight as compared with pure water, being of course augmented by its foreign contents. Mr Kirwan* has given the following formula for calculating the proportion of saline substances in a water of known specific gravity: "subtract the specific gravity of pure water from that of the water examined and multiply the remainder by 1,4. The product is equal to the saline contents in a quantity of the water denoted by the number employed to indicate the specific gravity of distilled water. Thus suppose the specific gravity of the water = 1,079, and that of pure water = 1,000, then 79 × 1,4 = 110,6 = saline contents in 1000 of the mineral water."

This is a useful formula, but open to certain objections; and as it is often of considerable importance to acquire a just knowledge of the proportion of foreign bodies in water, it is advisable to conjoin the above method with the following:

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* Essay on Mineral Waters, p. 145.

Proportion of foreign bodies how ascertained.

iii. Evaporate a given weight, say, 1000 parts to dryness, and expose the residue for 24 hours to a temperature not exceeding 300° upon a platinum capsule; weigh it while warm, and the mean obtained from this and the former experiment, will give the proportion of dry saline ingredients within an error of two per cent. Thus suppose 1000 parts of the above-mentioned water give by evaporation 114,4 dry residue, then $110,6 + 114,4 = 225 \div 2 = 112,5 =$ quantity of saline matter in a dry state (salts deprived of water of crystallization) existing in the mineral water under investigation.

iv. Having by these preliminary operations ascertained the relative *quantity* of foreign matter in the water under examination, the *nature* of the substances present is next to be inquired into.

Substances usually met with.

1768. The substances which have been found in mineral waters are extremely numerous, but those which ordinarily occur, are the following:

Oxygen.
Nitrogen.
Carbonic acid.
Sulphuretted hydrogen.
Carbonate of lime.
Carbonate of magnesia.
Carbonate of iron.
Muriate of magnesia.
Sea salt.
Sulphate of magnesia.
Sulphate of soda.
Sulphate of lime.

Oxygen and nitrogen.

a. Oxygen and nitrogen exist in the greater number of spring waters in the proportions constituting atmospheric air; the proportion of nitrogen is, however, not unfrequently predominant. These gases give no peculiar flavour to the water.

Carbonic acid.

b. Carbonic acid renders mineral waters sparkling and effervescent: it is detected by occasioning a precipitate in aqueous solution of baryta, which dissolves with effervescence in dilute muriatic acid.

Sulphuretted hydrogen.

c. The presence of sulphuretted hydrogen is known by its peculiar disagreeable smell; by the production of a black precipitate on dropping into the water a solution of nitrate of silver, and by the deposition of sulphur on adding a few drops of nitric acid.

Carbonates.

d. The carbonates are dissolved in the water by excess of carbonic acid, and consequently fall upon its expulsion by boiling. Carbonate of lime and magnesia are deposited in the form of a white precipitate. Carbonate of iron occasions the separation of a rusty brown ferruginous powder, and the water is blackened by a few drops of tincture of galls.

Detection of iron.

e. Mr R. Phillips, in his analysis of Bath waters, has shown that the delicacy of galls, as a test for iron, is curiously affected by the presence of certain salts: if the iron be in the state of protoxide, its detection is facilitated by salts with a base of lime, and by alkalies; if in the state of peroxide, lime prevents the action of the test. This is well shown by dissolving a *very* minute proportion of proto-sulphate of iron in a glass of distilled water, and adding a drop of tincture of galls, which occasions no immediate discoloration; but a drop of lime water, or other alkali, instantly renders the presence of iron evident; so that the quantity of iron present in a water cannot be correctly judged of by the degree of precipitation occasioned in it by tincture of galls.

f. Ferro-cyanate of potassa is also a good test to show minute quantities of iron in water, by the blue precipitate which it occasions; its action is aided by previously adding two or three drops of nitric acid to the water; but it is an equivocal test compared with galls.

— of chlorides,

g. The presence of muriatic salts and of chlorides, is indicated by a white cloud on adding sulphate of silver.

— of sulphates,

h. The sulphates, when present in water, afford a white precipitate on the addition of nitrate of baryta, which is insoluble in nitric acid.

— of lime,

i. Lime is recognised by a white cloud on dropping oxalate of ammonia into the water. A portion of the precipitate collected upon leaf platinum, and heated before the blow-pipe, may be burned into quick-lime.

— of magnesia.

k. Magnesia is rendered evident by adding carbonate of ammonia which throws down the lime, and subsequently pouring in phosphate of soda, which, when magnesia is present, carries a portion of it down in the form of a granular precipitate of ammoniaco-magnesian phosphate.

Such are the readiest means of recognising the presence of the various substances that commonly occur, by the action of re-agents or tests; and, having gained such general information, we next proceed to the analysis of the water, in order to ascertain the relative proportions of the gaseous and saline ingredients which it holds dissolved.

SECTION III. *Analysis of Mineral Waters.*

To ascertain the gaseous contents.

1769. v. To ascertain the relative proportions of the gaseous contents of water with perfect accuracy, is a very difficult undertaking, and rarely necessary; the following method is sufficiently precise in all ordinary cases of analysis. Provide a Florence flask capable of holding rather more than a measured wine-pint, which quantity of the water under examination is to be introduced into it, and a cork carefully fitted to its neck, through a perforation in which is inserted a glass tube one-eighth inch in diameter, rising perpendicularly about 18 inches, and then bent so as to pass conveniently under the shelf of the mercurio-pneumatic apparatus. (Where a sufficiency of mercury cannot be procured, warm water may be substituted, if only carbonic acid be present, and it may be absorbed by transferring the jar containing it to a solution of potassa.) The flask should be placed over an argand lamp, and heat gradually applied till the water fully boils. The gas evolved is to be collected in the usual way, in a graduated jar over quicksilver, and submitted to the following examination :—

Carbonic acid. vi. Throw up a small quantity of solution of potassa, which, if carbonic acid be present, will absorb it, and the quantity will be shown by the diminution of bulk.

Oxygen. vii. Introduce the remaining air, or a portion of it into a small bent tube, containing a bit of phosphorus; heat it so as to kindle the phosphorus, and note the diminution of bulk when cold. It is proportional to the oxygen present, and if equal to one-fifth of the whole bulk, the gas may be regarded as atmospheric air.*

Sulphuretted hydrogen. viii. If sulphuretted hydrogen be present it may be separated by a strong alcoholic solution of iodine, which rapidly absorbs it, and scarcely takes up more than its own volume of carbonic acid gas. Chlorine, added to a mixture of sulphuretted hydrogen and carbonic acid, will also produce the absorption of the former if a little water be present; but it cannot be conveniently used over mercury.

Carbonates. ix. During the ebullition it not unfrequently happens that a precipitation ensues, indicating that the substances thrown down were dissolved by carbonic acid; and in that case they should be separated upon a filter A, after which the remaining water may be evaporated to dryness in a glazed porcelain basin; the dry residue transferred to a silver capsule, and perfectly desiccated at a temperature not exceeding 500°. B.

The precipitate A may consist of carbonate of lime, of carbonate of magnesia, or of oxide of iron; or it may be a mixture of the three; dissolve it in dilute muriatic acid, and add oxalic acid which throws down oxalate of lime; separate this by filtration, and saturate the filtrated portion with carbonate of ammonia, which precipitates the peroxide of iron, and having removed this, evaporate the residuary mixture, and expose the dry salt to a red heat in a small platinum capsule; the magnesia, if any were present, will remain; if not there will be no residue, for the oxalic acid and muriate of ammonia will be destroyed and volatilized.

100 parts of oxalate of lime indicate 77 of carbonate of lime.

Iron. 100 parts of red oxide of iron indicate 90 of black oxide, or 143 of carbonate of iron. When carbonic acid holds iron in solution, the metal is in the state of protoxide, and if air be excluded, it requires long boiling to decompose it; for the same reason, if the water be exposed, under the exhausted receiver of the air-pump, it does not readily become brown, as is the case when it is exposed to air; a drop or two of nitric acid facilitates the deposition of the red oxide.

Magnesia. 100 parts of pure magnesia are equivalent to 213 of carbonate of magnesia.

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* In separating oxygen a solution of nitric oxide in protosulphate of iron may sometimes conveniently be employed, but it does not give so accurate a result as the action of phosphorus.

x. The dry residue B, is to be digested in six or eight parts of boiling alcohol, specific gravity 0,817, which will take up muriate of magnesia, and in some rare cases (where no sulphates are present) muriate of lime. Filter off the alcoholic solution, and wash the residue c with a little fresh alcohol, which add to the former, and evaporate to dryness D. The dry mass D, exposed for some time to a heat of 500°, is generally pure muriate of magnesia, if it contain muriate of lime, the latter earth may be separated by solution of oxalic acid, in the state of oxalate of lime.

Conversion of the muriates into sulphates.

It is convenient in some cases, to convert the muriates of lime and magnesia into sulphates, by pouring upon them excess of sulphuric acid, evaporating to dryness, and heating the dry mass red hot. The sulphate of magnesia may then be almost completely separated from the sulphate of lime, by a small quantity of cold water; or a saturated solution of sulphate of lime may be used, which takes up the sulphate of magnesia, and, of course, leaves the sulphate of lime.

The alcohol will also take up a very minute portion of sea-salt, which, however, is too small to require estimation.

xi. The residue c, insoluble in alcohol, may contain sea-salt, sulphate of soda, sulphate of magnesia, and sulphate of lime; digest it in ten parts of boiling distilled water, which, when cold, will have taken up every thing but sulphate of lime, of which an inappreciable portion only will have been dissolved; separate the solution into two equal portions, *a* and *b*.

Sea-salt.

To *a* add nitrate of silver, and wash and dry the precipitate, which is chloride of silver, and of which 100 parts indicate 41 of sea-salt.

To *b* add acetate of baryta as long as it occasions a precipitate, which is sulphate of baryta, and which is to be separated, dried and weighed. 100 grains are equivalent to 60,5 of sulphate of soda, and to 51 of sulphate of magnesia.

Sulphate of magnesia.

In order to ascertain the quantity of magnesia present, and consequently the quantity of sulphuric acid belonging to it, evaporate the liquid filtered off the barytic precipitate E to dryness; it will contain sea-salt, acetate of soda, acetate of magnesia, and, probably, a portion of the added acetate of baryta; ignite the dry mass, and wash it to separate the sea-salt and soda; magnesia, and carbonate of baryta will remain insoluble, upon which pour dilute sulphuric acid; digest, filter, and evaporate the clear liquor to dryness; it is sulphate of magnesia, equivalent of course to the original portion of the salt; deduct the sulphuric acid contained in it from the whole in the precipitate E, and the remainder will give the quantity united to the soda.

—of lime.

xii. To estimate the quantity of sulphate of lime in the water, the residue of the evaporation of one pint may be washed with cold saturated solution of sulphate of lime, which will dissolve every thing but that sulphate, and which may thus be obtained and weighed; or, add oxalate of ammonia to a given quantity of the boiled and filtered water, collect the precipitate, and dry it at a heat of 500°. 100 grains of this oxalate indicate 104 of dry sulphate of lime.

Mode of drawing up the analysis.

xiii. Such are the general components of mineral waters, and the means of ascertaining their relative quantities. Let us suppose the following results have been obtained, with a view to illustrate the mode of drawing up the analysis. By the process v, twelve cubical inches of gas have been expelled during the ebullition of a pint of water. The exposure to solution of potassa has occasioned a diminution of eleven cubical inches, which, it having been previously ascertained that no sulphuretted hydrogen was present, may be considered as carbonic acid. The remaining gas thrown up into a tube containing a portion of phosphorus, and heated, suffers scarcely any diminution, and the phosphorus does not burn: hence it may be regarded as nitrogen. The gaseous contents, therefore, of the water under examination are in the wine-pint—

Carbonic acid	11 cubic inches.
Nitrogen	1 ditto.[*]

If sulphuretted hydrogen be present, it is best to have recourse to a separate operation to estimate its quantity: for this purpose collect the gas as before, and throw up into it a small quantity of alcoholic solution of iodine. The absorption denotes the quantity of the gas. (viii.)

xiv. The next step of the operation relates to the examination of the precipitate deposited during ebullition, (ix. A.) Let us suppose the weight of oxalate of lime to be 3 grains, of oxide of iron 1,5 grain, and of magnesia 1 grain; then the above data give

	Grains.
Carbonate of lime	2,2
Carbonate of iron	2,4
Carbonate of magnesia	2,1

xv. The alcoholic solution (x.) may be diluted with water and tested by oxalic acid for lime; if absent, evaporate to dryness as directed. Let us suppose the residue to be

Muriate of magnesia . . . . 5 grains.

If the quantity of muriate of magnesia be considerable, greater accuracy is ensured by converting it into sulphate, which is done by placing it in a capsule of platinum, pouring upon it sulphuric acid, evaporating to dryness, and heating the dry mass to dull redness. 100 grains of this dry sulphate of magnesia indicate 94 of muriate of magnesia; hence the water under examination would have given 5,35 grains = 5 grains of muriate.

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[*] Of this nitrogen, a small portion will probably have been derived from the air in the tube connecting the flask with the pneumatic apparatus; a little practice soon enables the operator to ascertain when it has been expelled: or it may be received entire, and afterwards deducted from the whole produce.

If the alcoholic solution contain muriate of lime, that earth must be previously separated by oxalic acid; and 100 parts of oxalate of lime are equivalent to 85 of dry muriate of lime.

xvi. The aqueous solution of the residue (c. xi.) being divided into two portions, let us suppose the portion *a* xi. to afford 8,5 of chloride of silver, which indicates of sea-salt 3,5 grains = 7 grains in the pint.

xvii. Let us assume, that the precipitate of sulphate of baryta *b* xi. weighs 15 grains, indicating of

Sulphuric acid	5,1 grains.

The process directed in xi. furnishes of

Sulphate of magnesia	3,75 grains,

which contain 2,5 grains of sulphuric acid, and which deducted from 5,1 grains leave 2,6 grains, which are adequate to the formation of

Sulphate of soda	4,65 grains.

So that the pint (the water having been divided into two equal portions) would contain of

Sulphate of magnesia 3,75 × 2 = 7,5 grains.
Sulphate of soda . . 4,65 × 2 = 9,3 grains.

xviii. The addition of oxalate of ammonia, or oxalic acid, to a pint of the boiled water (xii.) furnishes a precipitate of 4,7 grains of oxalate of lime, indicating of

Sulphate of lime	5 grains.

xix. To give a general view, therefore, of the components of the mineral water which has thus been examined, we should place them as follows:—

General view of the contents.

One wine pint contains

	Cubic inches.
Carbonic acid	11
Nitrogen	1
Gaseous contents	12

	Grains.
Carbonate of lime	2,20
Carbonate of iron	2,40
Carbonate of magnesia	2,10
Muriate of magnesia	5,00
Sea salt	7,00
Sulphate of magnesia	7,50
Sulphate of soda	9,30
Sulphate of lime	5,
Aggregate weight of solid contents	40,50

Substances occasionally present.

xx. Besides the substances now enumerated, and which may be considered as the most frequently occurring ingredients in mineral waters, there are others occasionally present of which the following is an enumeration, with the best methods of detecting them:

Carbonate of soda.

a. Carbonate of soda is known to exist in water, when, after having been boiled down to half its bulk, and, if necessary, filtered, it reddens turmeric paper, and restores the blue of litmus reddened by vinegar; it also affords an effervescent precipitate with nitrate of baryta, soluble in dilute nitric acid. This carbonate is incompatible with the soluble salts of lime.

Muriate of lime.

Muriate of lime may also be used to detect the alkaline carbonates, with which it affords a precipitate of carbonate of lime. Carbonate of soda is distinguished from that of potassa, by the latter affording a precipitate in neutral muriate of platinum, which the former does not. Carbonate of ammonia is obviously discoverable by its smell, when acted on by caustic fixed alkali or lime.

Silica.

b. Silica is detected by evaporating the water to dryness, and boiling the residue in dilute muriatic acid. The silica, if present, remains as a white powder not altered by a red heat, but instantly fusing with a particle of carbonate of soda.

Boracic acid.

c. Boracic acid and borax have been found in certain lakes in India, and in some parts of Italy. To detect boracic acid, evaporate to one-eighth the original weight of water, and add carbonate of soda as long as it occasions any precipitate; boil and filter. The filtered liquor will contain borate of soda, with some other salts of the same basis; evaporate to dryness in a platinum crucible, and digest the residue in three or four parts of sulphuric acid, diluted with its bulk of water. If boracic acid be present, it will separate in micaceous crystals.

Alumina.

d. Alumina has been found in a few mineral waters in the state of a sulphate. It may be separated by the following process: Evaporate to dryness, digest in alcohol, and re-dissolve the residue in eight parts of water; filter and add oxalic acid, which throws down lime, and which, being separated, leaves magnesia and alumina in solution. Carbonate of ammonia throws down the alumina and leaves the magnesia.

Pure ammonia throws down both alumina and magnesia. These earths may be separated by solution of potassa, which dissolves the former but not the latter.

Manganese.

e. Manganese is sometimes found in water, but only in very small proportion, so as not to amount to more than a trace. Dr Scudamore found a trace of manganese in the waters of Tunbridge Wells, and it has never been discovered in larger proportion.

Nitrates.

f. It has been said that certain nitrates are occasionally present in water, but such solutions can scarcely be called *mineral waters.* If nitrate of lime be present, it will be taken up from the residue of evaporation by alcohol, and may be decomposed by carbonate of potassa, so as to afford carbonate of lime and crystals of nitre.

Lead.

g. It sometimes happens that water contains lead, which may be detected by evaporation to one-eighth its bulk, adding a few drops of nitric acid, and then hydriodate of potassa, which gives a yellow insoluble precipitate; and hydrosulphuret of ammonia, which forms a deep brown or black cloud. These precipitates may be reduced by heating them before the blow-pipe upon charcoal, mixed with a little black flux.

Vegetable and animal matter.

h. If vegetable or animal matter be contained in water, it gives it a brown colour, especially when evaporated. It may be destroyed in the dry residue by igniting it with a small addition of nitrate of ammonia.

The following analyses of mineral waters may be advantageously consulted by the student, as containing a variety of useful details which are necessarily omitted in the above observations:—*Analysis of the Hot Springs at Bath* by RICHARD PHILLIPS, Esq. *Analysis of the Brighton Chalybeate*, by Dr MARCET. *Analysis of the Tunbridge Wells Waters* by Dr SCUDAMORE. Mr CHILDREN's *Translation of* THENARD's *Essay on Chemical Analysis*, chap. vi.*

Dr Murray's method.

* Dr Murray, of Edinburgh, remarks that all mineral waters are either saline, or may be reduced under that division, by expelling any excess of carbonic acid by heat, expelling or decomposing sulphuretted hydrogen in like manner, or removing iron by appropriate methods. He then gives a general formula for the analysis of mineral waters, as follows:

1. Reduce the water by evaporation, as far as can be done without occasioning any sensible precipitation or crystallization.

2. Add to the water, thus concentrated, a saturated solution of muriate of baryta as long as any precipitation is produced, taking care to avoid adding an excess. By a previous experiment, let it be ascertained whether this precipitate effervesces or not with diluted muriatic acid, and whether it is entirely dissolved: if it is, the precipitate is of course carbonate of baryta, the weight of which, when it is dried, gives the quantity of carbonic acid; 100 grains containing 22 of acid. If it do not effervesce, it is sulphate of baryta, the weight of which, in like manner, gives the quantity of sulphuric acid; 100 grains, dried at a low red heat, containing 34 of acid. If it effervesce, and is partially dissolved, it consists of both carbonate and sulphate. To ascertain the proportion of these, let the precipitate be dried at a heat a little inferior to redness, and weighed; then submit it to the action of dilute muriatic acid; after this, wash it with water, and dry it by a similar heat, its weight will give the quantity of sulphate, and the loss of weight that of the carbonate of baryta.—By this operation the carbonic and sulphuric acids are entirely removed, and the whole salts in the water are converted into muriates; it remains, therefore, first to discover and estimate the quantities of the bases present and then, to complete the analysis, to find the quantity of muriatic acid originally contained.

3. Add to the clear liquid a saturated solution of oxalate of ammonia as long as any turbid appearance is produced. The lime will be thrown down in the state of oxalate. The precipitate being washed, may be dried; but as it cannot be exposed to a red heat without decomposition, it can scarcely be brought to any uniform state of dryness with sufficient accuracy to admit of the quantity of lime being estimated from its weight; it is, therefore, to be calcined with a low red heat, by which it is to be converted into carbonate of lime, 100 grains of which are equivalent to 56 of lime. But as a portion of carbonic acid may be expelled if the heat is raised too high, or a little water retained if it is not high enough, it is proper to convert it into sulphate, by adding sulphuric acid to a slight excess, and then expose it to a full red heat. The dry sulphate of lime will remain, 100 grains of which contain 41,5 of lime.

4. To the clear liquid poured off after the precipitation of the oxalate of lime, heated to 100°, and, if necessary, reduced by evaporation, add a solution of carbonate of ammonia; and immediately drop in a strong solution of phosphoric acid or phosphate of ammonia, entirely free from any impregnation of lime, continuing this addition with fresh portions, if necessary, of carbonate of ammonia, so as to preserve an excess of ammonia in the liquid as long as any precipitation is produced. Let the precipitate be washed: when dried by a heat not exceeding 100°, it is the phosphate of ammonia and magnesia, containing 0,019 of this earth; but it is better to convert it into phosphate of magnesia by calcination for an hour at a red heat: 100 grains, then, contain 40 of magnesia.

5. Evaporate the liquid remaining after the preceding operations to dryness, and expose the dry mass to heat as long as any vapours exhale, raising it towards the end to redness. The residual matter is muriate of soda, 100 grains of which are equivalent to 53,3 of soda and 46,7 of muriatic acid.

6. Combine the elements obtained by the analysis (taking the quantity of muriatic acid existing in the muriate of soda), in binary combinations, according to the known proportions in which they unite: the excess or deficiency of muriatic acid will then appear; and the amount of the excess being subtracted from the quantity of muriatic acid contained in the muriate of soda obtained,—or the amount of

CHAPTER VI.

VEGETABLE SUBSTANCES.*

Principal ingredients.

1770. VEGETABLE substances, though distinguished from each other by peculiar characters, present several circumstances of agreement as to chemical properties. Oxygen, hydrogen, and carbon are their principal ingredients, to which a certain proportion of nitrogen is sometimes added; and variations in the proportions, and mode of combination, of these elements, occasion the great diversity, which subsists among the products of the vegetable kingdom. They are all susceptible of decomposition by heat alone; but we cannot always as in bodies of the mineral kingdom, proceed from a knowledge of their components to the actual formation of the substances themselves. It is not probable, indeed, that we shall ever attain the power of imitating nature in these operations. For in the functions of a living plant, a directing principle appears to be concerned, peculiar to animated bodies, and superior to, and differing from, the cause which has been termed chemical affinity.

Distinction between inorganic and organic compounds.

1771. The distinction (as has been well observed by Berzelius†) between inorganic and organic compounds appears to be this. The inorganic are composed either of combustible bodies only, or of one or more of those bodies in the state of oxides. When constituted of the latter, each combustible base is united with a portion of oxygen, which belongs exclusively to it, and which accompanies it, when it is detached from combination. If, for example, we resolve sulphate of potassa into its immediate principles, the oxygen, which, with the sulphur constitutes sulphuric acid, and that, which exists in potassa, remain attached to the combustible bases, sulphur and potassium. But in organic compounds containing oxygen as an element, we have two or more combustible bases, united to one portion of oxygen, which cannot be said to belong more to the one base, than to the other; and which would not suffice to bring any one of those bases to its maximum of oxidation.

1772. The productions, of which the chemical history is about to be offered, may be regarded as the *immediate* or *proximate*

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the deficit being added to that quantity, the real quantity of muriatic acid will be obtained. To ensure perfect accuracy, it may be proper to estimate directly the quantity of muriatic acid in a given portion of water, by abstracting any sulphuric or carbonic acid by nitrate of baryta, and then precipitating the muriatic acid by nitrate of silver or nitrate of lead. When the quantity is thus found, the quantities of the other ingredients must bear that proportion to it which will correspond with the state of neutralization.

The results of the analysis may always be stated in these three modes:—1. The quantities of the acids and bases. 2. The quantities of the binary compounds, as inferred from the principle that the most soluble compounds are the ingredients. 3. The quantities of the binary compounds, such as they are obtained by evaporation or any other direct analytic operation.—See *Trans. Roy. Society of Edinburgh*, viii. 250; and *Thomson's Annals*, x. 93, 169. vii. 43. vi. 256, 347.

* From Henry's *Chemistry* ii. 161, &c.

† Ann. de Chim. 80. 37.

principles of vegetables; for we may presume, generally speaking, that they exist in the living plant in a state indentical with that, under which chemical processes exhibit them. It is not so when we proceed to the *ultimate* analysis of vegetables; for, in that case, we obtain compounds, which formed no part of the vegetable structure, and which result from an entirely new arrangement of the elements composing it. Acetic and carbonic acids, for example, are obtained by the destructive distillation of several vegetable substances, in which neither of those acids existed ready formed, but only their elements.

Ultimate analysis.

1773. The destructive distillation of vegetables, or the subjecting them to the action of heat in close vessels, with a view to collect both the condensible and aëriform products, was, until within a few years past, the only method employed to determine the proportion of their ultimate elements; but more refined and perfect modes of analysis were introduced by Gay-Lussac and Thenard, which have afforded results much more deserving of confidence.* The object of these improved processes, which are equally applicable to vegetable and animal substances, is to convert the whole of the carbon into carbonic acid, and the whole of the hydrogen into water, by means of some compound containing oxygen in so loose a state of union, as to give it up to those bases at the temperature of ignition. The following illustrations are intended to explain the rationale of the process.

SECTION I. *Of the Analysis of Organic Substances.*

1774. i. If we have charcoal only, mixed with incombustible matter, and wish to determine its quantity, all that is necessary is to expose a known weight of the substance under examination, in a state of perfect mixture with a fit oxide, to a red heat, and to collect the carbonic acid. From the volume of this gas, its weight may be easily calculated (82); and of this weight six parts in 22 are pure carbon.

Charcoal with incombustible matter.

ii. Let us next suppose that we are operating on a compound of charcoal with hydrogen. This, if solid, must be mixed with an excess of the oxidated substance which is employed, and the carbonic acid collected as before. Calculating, by the same method, the quantity of charcoal which it contains, we obtain the weight of one element of our unknown compound; and this, deducted from the weight which was submitted to experiment, gives the weight of the remaining element, hydrogen. To attain greater certainty, the water, which is formed, may be actually collected by a proper addition to the apparatus, either at the same operation with the carbonic acid, or at another, performed expressly for the purpose. Of this water, one part in nine is hydrogen. The carbon, calculated from the carbonic acid, and the hydrogen from the water, should

Charcoal and hydrogen.

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* Recherches Phys. Chim. ii.

together make up precisely the weight of the compound on which we have operated.

Carbon, hydrogen and oxygen.

iii. A third case may be supposed, in which carbon and hydrogen are united with oxygen, but yet not with enough to convert them entirely, at a high temperature, into carbonic acid and water. In this case the first steps of the operation are the same as before. But on summing up the results, the weight of the carbon and hydrogen, discovered in the products, will be found to fall short of the weight of the substance submitted to experiment. If no other product has been formed besides water and carbonic acid, the deficiency may safely be placed to the account of oxygen. For example, if from 10 grains of a supposed compound of hydrogen and carbon, we obtain by ignition with an oxide, 22 grains of carbonic acid and 9 grains of water, these are equivalent to 6 grains of carbon and 1 of hydrogen: but $6 + 1 = 7$ leave a deficiency of 3 grains, which may be inferred to be oxygen. To verify this conclusion, if at all doubtful, it may be proper to examine what quantity of oxygen has been lost by the oxide employed to effect decomposition; and if this fall short of the oxygen contained in the carbonic acid, and in the water, then the quantity required to make up the sum, must have previously existed in the subject of analysis. For instance, in the supposed case, we find 16 grains of oxygen in the carbonic acid and 8 in the water obtained, together 24; but if the oxide can be shown by experiment, to have lost only 21 grains, we may safely conclude that 3 grains pre-existed in the compound.

Carbon, hydrogen, oxygen and nitrogen.

iv. In a few vegetable substances, and in almost all animal ones, besides carbon, hydrogen, and oxygen, azote or nitrogen exists as a component, and its quantity requires to be determined. With a proper attention to the details of the process, this fourth element may be obtained in the state of a gas, which remains after absorbing the carbonic acid by solution of potassa, and the oxygen (if any) by a fit agent. From the volume of the gas, its absolute weight may easily be calculated. (82).

Elements united in definite proportions.

1775. Such is an outline of the process employed for the decomposition of vegetable and animal substances, divested of all details for the purpose of rendering its objects and results more intelligible. These details, however, are of considerable importance in practice, and will, therefore be presently stated at length. It may be proper, however, first to remark, that all the analyses which have been thus performed, and which are worthy of confidence, conspire to prove that the elements of organized, like those of inorganic matter, are united in definite proportions; and farther, that the law of simple multiples holds strictly with respect to the elements of organic bodies. We may derive, therefore, as has been well observed by Dr Prout, the most valuable assistance in our researches into organic compounds, from the use of Dr Wollaston's scale of chemical

Dr Wollaston's scale may be used.

equivalents.* To fit it for this purpose he recommends that it be extended a little, by pasting two slips of drawing paper on its edges, of such a breadth as just to lap over and cover the margins containing the names of the chemical substances generally marked upon it, and to coincide with the graduated edges of the slide. On these slips of paper are to be marked the multiples of an atom of oxygen, hydrogen, and carbon, from one to ten; and of azote from one to four or five or more. Thus prepared, it will be easily applied, by all who are acquainted with the principle of the instrument, to the purposes of facilitating and verifying analyses, the results of which can only be correct when they agree with some of the proportional numbers, marked upon the scale. For example, an analysis showing 48 parts of oxygen, 6 of hydrogen, and 36 of carbon, in a vegetable compound, or quantities proportional to these, agrees with six atoms of each of those elements. But such an alteration of any of those numbers as would indicate the fraction of an atom (the reduction of the carbon, for instance, to 34) would be inconsistent with the law of simple multiples, and would suggest the necessity of a fresh appeal to experiment.

Gay-Lussac and Thenard's method.

1776. The agent, first employed by Gay Lussac and Thenard in the combustion of organic substances, was the *chlorate of potassa* (827), applied by means of an ingenious apparatus, which is described in the second volume of their *Recherches Physico-chimiques*, and also in Mr Children's translation of Thenard on Chemical Analysis. For chlorate of potassa, Gay-Lussac afterwards substituted the *peroxide of copper*, which, being found to afford more accurate results, with a less complicated apparatus, and fewer difficulties of manipulation, is now generally preferred, especially in the analysis of animal compounds. Peroxide of copper may be prepared for this purpose by calcining on a muffle the scales or filings of that metal, pulverizing them repeatedly, and again spreading them on the muffle; or by calcining the nitrate of copper at a low red heat. Several variations in the method of proceeding have been recommended by different experimenters. The tube, for containing the mixture of the oxide and body to be analysed, is by some preferred of copper, by others of glass; and the heat has been applied, either by encompassing the tube with burning charcoal, or with the flame of a spirit lamp. Glass tubes of about 1-3d of an inch bore, or of a diameter adapted to the quantity operated upon, seem, on the whole, to be preferable to metallic ones; and the heat of a spirit lamp, used in the most improved manner, appears to be adequate to effect a complete decomposition of most vegetable and animal compounds.

Solids.

1777. If the substance be a solid, from 3 to 5 grains carefully dried, (which is best done by placing it in fine powder under

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* Ann. of Philos. iv. 210.

Fluid. Dr Ure's method.

an exhausted receiver along with sulphuric acid,)* are to be triturated in a glass or porphyry mortar, first by themselves, and then with 120 to 200 grains of the peroxide of copper, added by degrees, so that the substance and the oxide may be thoroughly incorporated. This mixture must be transferred, with the most scrupulous care to avoid loss, into the glass tube, and a little more of the protoxide must be triturated in the mortar, to collect any remains of the substance under analysis, and then added to the contents of the tube. Over these, 20 or 30 grains of the peroxide may be placed; and the remainder of the tube may be filled with perfectly dry amianthus. The peroxide should either have been recently cooled from a state of ignition, or, as advised by Dr Ure, have been suffered to imbibe all the moisture it is capable of absorbing from the air, and assayed for the quantity, which, in that case, must be deducted from the loss of weight, sustained by the peroxide in the experiment. To operate on a fluid, Dr Ure incloses it in a small glass bulb capable of holding three grains of water, and having a small pointed orifice. It is easy to fill such a bulb by first expelling the air from it by heat, and then immersing its orifice in the liquid. The bulb thus filled, and carefully weighed, is to be placed at the bottom of the tube, and covered with the requisite quantity of the peroxide of copper. In all cases, the tube, with its contents, should be accurately weighed, and its weight registered.

Pl. 7.

For the purpose of applying heat to the tube, and obtaining the gaseous products with only a small quantity of mercury, an useful apparatus has been contrived by Dr Prout. fig. 124.†

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* An apparatus for drying substances in vacuo, at a temperature of 212° Fahrenheit, is described by Dr Prout in Ann. of Phil. vi. 272.

Dr Prout's apparatus,

† Two square upright pillars are morticed into a square tray (*a a* at the bottom of the figure) about 3-4ths of an inch deep, and are fixed at the top by brass screws into a flat shelf of wood, 3 in. broad at each end, and 5 in the middle, in which is an oval slit or hole 4 1-2 inches long and 1 1-4 wide, distant 1 3-4 inches from the right hand extremity of the shelf. Below this is another shelf, *b b*, which is moveable by a rack and pinion worked by a small handle, as shown at *f*. Into a shallow cavity in this shelf is fixed a cistern of copper covered with hard varnish (cast iron would be better) and having a deep cylindrical cavity or well at *d*. This, to economize mercury, may occasionally be filled with a plug of wood or cast iron. The cistern may be of any convenient dimensions, as 5 1-2 long by 1 1-2 wide, and in its bottom, an opening is required about 5-8ths of an inch diameter for admitting the glass tube *g g*, which is secured in its place by a perforated cork, and is passed also through the axis of a brass spirit lamp, which, as well as the wick, has a circular hole for the purpose. The lamp is placed on a small shelf, perforated also, and moveable by the rack and pinion. A small mirror of tin, with the concave side downwards, is screwed to the bottom of the cistern, to guard the cork from being burned by the heat of the lamp. At *k* is a turning button with a semicircular notch for securing in an upright position the jar *h*, which should be capable of containing 7 or 8 cubical inches.

The tube *g g* being fixed in its place, and the jar *h* filled with and inverted in mercury, the spirit lamp is set as high as its carriage will permit, and lighted. The part of the tube, which is surrounded by the burning wick soon becomes red hot, and gas is evolved. When it ceases to issue, the lamp may be gradually lowered, so as to heat successively the whole of the tube, and then moved upwards to the top. When this has been skilfully performed, the whole of the substance under analysis will be found to have been decomposed; but to insure accuracy, its contents may be taken out, triturated in a mortar, and subjected to a repetition of the same operation. The gases obtained must be exposed to the action of liquid potassa, which will absorb the carbonic acid. In measuring the residue, it will

Mr Cooper's apparatus

By the apparatus of Dr Prout, a part only of the tube and its contents can be heated at once. This is of little consequence when solid bodies are acted upon; but in the decomposition of liquids, or of solids yielding liquid products, it is desirable to ignite a greater length of the tube at a time. To effect this, Mr Cooper, of Lambeth, employs a lamp, which appears to be very well adapted to the purpose. It is of tin, in the shape of a parallelopiped, 8 inches long and 1¼ square, with 5 flat wick-holders fixed at equal distances and at a small angle with its upper surface, each wick-holder being half an inch broad and 3-8ths of an inch high. Of these lamps two are necessary, and they are placed in a small tin tray which is raised on four feet, and has a longitudinal slit in the middle 7¾ inches long and 3-8ths of an inch wide. On this tray the lamps are placed with their wicks opposite to each other; and the tube, containing the mixture to be decomposed, which is of green glass, sealed hermetically at one end, from 10 to 14 inches long, and about the diameter of a small quill, is placed horizontally over the wicks at a suitable distance, one end of the tube having been first bent by a lamp into such a form, that its open extremity can be placed under a jar inverted in mercury. It is easy, by lighting one or more wicks, and altering the distance of the flames from the tube, and of the lamps from each other, to modify the application of the heat as the circumstances of the experiment may require. The alcohol, to prevent its too rapid combustion, Mr Cooper dilutes with water to the sp. gr. of about ,860.

might be combined with Prout's.

It would not be difficult to combine in one apparatus, the advantages of Dr Prout's method of operating with those of Mr Cooper's mode. To effect this the open extremity of the tube, placed horizontally over the wicks of the spirit lamps, might be admitted into the hole at the bottom of the mercurial cistern. The only disadvantage of this method of proceeding would be that the open extremity of the distilling tube being bent, the contents of the tube could not be got out, for a second trituration and ignition, without breaking it, an inconvenience which does not exist when a straight tube is employed as in Dr Prout's apparatus.

1778. Those, who prefer employing the heat of charcoal, will find the description of an apparatus, contrived by Dr Ure for that purpose, in the Phil. Trans. for 1822, p. 460. From observation, however, of the effects of the heat obtained by the combus-

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be necessary to equalize the level of the mercury within and without the receiver, by immersing it in the well *d*. The residuary gas will probably be nitrogen only, but it may be assayed for oxygen by nitrous gas as described (414.) The gases must of course be either measured at a mean of the barometer or thermometer, or the proper corrections made for deviations from these standards, as well as from aqueous vapour, by the rules already given page 82.

To collect the water, a separate operation on another portion of the substance is necessary. When this is done, the mercurial cistern may be removed; and such a condensing apparatus substituted, as will be obvious to persons conversant with chemical processes.

tion of alcohol, it appears to be fully sufficient with the advantage of being much more manageable than that of a charcoal furnace.

1779. The whole of the operations, connected with the ultimate analysis of vegetable and animal substances, require considerable skill; and some practice in them is necessary to enable a person, who is even conversant in the general processes of chemistry, to obtain accurate results. A single experiment should never be depended upon; but the analysis of each substance should be several times repeated, and a mean taken, of those which do not present any very striking disagreement, excluding those results which vary so much from the average, as to lead to a suspicion of some failure in the manipulations.

Objection to these methods.

1780. It may sometimes perhaps, on a first view, excite suspicion of the competency of these methods of ultimate analysis to afford accurate results, when we remark the very near coincidence not only with respect to the *kind*, but even to the *proportions* which have been thus deduced, of the elements of substances, differing essentially as to their chemical and sensible properties. In the instances of gum, sugar, and starch, the differences of composition, discovered by the experiments of Gay-Lussac and Thenard, are so extremely small, as not to indicate any difference either of the kind or the number of elementary atoms. The results, however, are not, in this or similar cases, to be pronounced, for that reason only, to be inaccurate; for it is probable that in vegetable substances it is not only the *number* and *kind* of the respective atoms, but the *mode of their arrangement*, which occasions their distinctive characters. This view of the subject is confirmed, when we observe the important changes in the properties of vegetable substances, and the convertibility of those, which appear so nearly allied, into each other, by slight causes, such as alterations of temperature, or weak chemical agents.

General conclusions.

1781. From a review of their experiments on the analysis of vegetable substances, Gay-Lussac and Thenard deduced the following general conclusions:

I. A vegetable substance is always acid, when the oxygen which it contains, is to the hydrogen, in a proportion greater than is necessary to compose water.

II. A vegetable substance is always resinous, or oily, or alcoholic, &c. when the oxygen, contained in it, is to the hydrogen, in a less proportion than in water.

III. A vegetable substance is neither acid nor resinous, but in a state analogous to sugar, gum, starch, lignin, &c. whenever oxygen and hydrogen enter into its composition in the same proportions as in water.

Without supposing then, that oxygen and hydrogen exist, as water, in vegetables, we may, for the sake of illustration, consider vegetable acids, as constituted of carbon, water, and oxygen;—the resins, alcohol, ether, &c. as composed of carbon, water, and hydrogen;—and bodies of the third class, as composed of carbon and water only. It should not, however, be omitted that some exceptions to the generality of these principles have been pointed out by Saussure,* and by Mr Daniell.†

1782. The products of the vegetable economy are either situated in particular organs or vessels, or are distributed throughout the whole plant. Sometimes they reside in the root or stalk; at others in the bark or leaves; at others they are peculiar to the fruit, the flowers, the seeds, or even to peculiar parts of these organs. When thus insulated they may readily be procured in a separate state; and, in several instances, nothing more is required than the labour of collecting them. Thus gum exudes from some trees, and manna issues from the branches of others. Sometimes, however, we are presented with a variety of substances mingled together, and requiring separation by processes which are sufficiently simple, and which consist in repose, filtration, pressure, washing, distillation at a gentle heat, solution by water and alcohol, and similar operations, that do not alter the nature of the bodies submitted to them. Organic products how obtained.

1783. The number of principles which have thus been extracted from vegetables, has of late years been greatly enlarged, and amounts at present to upwards of forty. Of these, the greater part are certainly entitled, by a train of properties sufficiently characteristic, to rank as distinct compounds. But others seem to be so nearly allied to substances, with which we have long been acquainted, that it can serve no useful purpose to assign to them a different place in the system. The unnecessary multiplication, indeed, of vegetable principles contributes rather to retard than to advance the progress of this difficult part of chemistry; and it is only in cases of decided and unequivocal differences of qualities, that we should proceed to the establishment of new species. Number.

SECTION II. *Gum.*

1784. GUM is contained in considerable quantities in the sap of many vegetables, and frequently appears as a spontaneous exudation. *Gum arabic* may be taken as a specimen of pure gum. Its specific gravity is about 1,4. It has a slightly yellow tint, and is translucent, inodorous, and insipid. It dissolves in water, forming a viscid solution, or *mucilage*, from which it may be obtained in its original state by evaporation; it is insoluble in alcohol, which, therefore causes a white precipitate in its aqueous solutions; it is also insoluble in ether and oils; Properties.

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* Thomson's Annals, vi. 431.

† Quarterly Journal, vi. 328.

it undergoes no change by exposure to air, and its aqueous solution does not ferment, but only becomes slightly sour when kept for a long time.

Mucous acid.

1785. Gum is decomposed by sulphuric and nitric acids: the former produces water, acetous acid, and charcoal; the latter, among other products, converts a portion of the gum into a white acid substance, called the *mucous acid*, and which is analogous to that obtained from sugar of milk, or *saccholactic acid*, under which head its preparation is mentioned: malic and oxalic acids are also formed.

Dilute sulphuric, and muriatic acids, dissolve gum without change.

Solvents of gum.

1786. The alkalies, and solutions of the alkaline earths, also dissolve gum, and the addition of acids occasions its partial precipitation without having undergone much apparent alteration. It combines, with a few of the other metallic oxides. A strong solution of permuriate of iron, dropped into a concentrated mucilage, forms a brown jelly of difficult solubility. Silicated potassa also occasions a white flaky precipitate in dilute mucilage, and is, according to Dr Thomson, a very delicate test of gum. By mixing caustic ammonia with a boiling solution of gum, and then adding subnitrate of lead, Berzelius obtained a white precipitate (*gummate of lead*) composed of

Composition.

Gum	61,75
Oxide of lead	38,25
	100.

If this compound be regarded as consisting of 1 proportional of gum, and 1 of oxide of lead, the number 181 might be assumed as the representative of gum, for 38,25 : 61,75 : : 112 : 180,8. But if we consider it as a compound of 2 of gum and 1 of oxide, then 90,5 would be the equivalent of gum, and the following numbers nearly agree with its composition, as deduced from experiment.

6 Proportionals of oxygen	8 × 6	= 48,0	=	53,3
6 ———— hydrogen	1 × 6	= 6,0	=	6,6
6 ———— carbon	6 × 6	= 36,	=	40,
		90		99,9

Pyromucous acid.

1787. Submitted to destructive distillation, gum affords carbonic acid and carburetted hydrogen gases, empyreumatic oil, water, and a considerable quantity of impure acetic acid, once considered as a peculiar acid, and distinguished by the term *pyromucous acid*, but now ascertained to be merely the acetic, holding in solution a portion of essential oil, and some ammonia, which last is disengaged on adding lime.

Other gums.

1788. There are several varieties of gum differing a little from each other. *Cherry-tree gum*, and *gum tragacanth* do not dissolve in cold water, but in other respects their properties resemble those of gum arabic. To these varieties the generic term of *Cerasin* has been given by some chemists.

Vegetable jelly.

1789. What has been termed *vegetable jelly*, is obtained from the recently expressed juice of various acid fruits, by gentle evaporation. It is a tremulous, soft coagulum, almost colourless after it has been well washed, and of an agreeable sub-acid taste. In cold water it is scarcely soluble, but in hot water it is abundantly dissolved; and when the solution cools, it again assumes a gelatinous form. By long boiling, however, it loses this property of coagulating; hence the necessity, in preparing jelly from certain fruits, of not submitting the expressed juice to protracted ebullition. Its solution in water is precipitated by infusion of galls. It seems probable that jelly is merely gum combined with some vegetable acid; for by exposing it on a sieve, an acid liquor drains off, and a hard transparent gum-like substance remains.

SECTION III. *Sugar.*

Preparation.

1790. SUGAR may be extracted from the juice of a number of vegetables, and is contained in all those having a sweet taste; that which is commonly employed is the produce of the *arundo saccharifera*, or *sugar-cane*, a plant which thrives in hot climates. Its juice is expressed and evaporated with the addition of a small quantity of lime, until it acquires a thick consistency; it is then transferred into wooden coolers, where a portion concretes into a crystalline mass, which is drained and exported under the name of *muscovado*, or *raw-sugar*. The remaining liquid portion is *molasses*, or *treacle*. A gallon of juice yields on an average about a pound of raw sugar.

1791. The juice, which flows spontaneously from incisions made in the American maple-tree, affords a quantity of sugar sufficient to render it a process worth following. Ripe fruits contain sugar in considerable quantity, and by long keeping after they have been dried, it appears in a granular state, on their surface. The juice of the carrot, and still more remarkably of the beet (*beta vulgaris*, Linn.) yield a considerable proportion of sugar. To obtain it from the latter vegetable, the roots, softened in water, are to be sliced; and the juice expressed. It is then to be boiled down, with the addition of a little lime, till about two-thirds remain, and afterwards strained. These boilings and strainings are repeated alternately, till the liquid attains the consistence of sirup, when it is left to cool. The sugar, thus extracted, retains somewhat of the taste of the root; but it may be purified by the operation used for the refining of West-India sugar, and it then loses its peculiar flavour. The quantity obtained varies considerably; but in general it may be stated at between four and five pounds from 100 pounds of the root, besides a proportion of uncrystallizable sirup. In Germany the expense has been calculated at about three pence per pound.*

From the experiments of Prout,† it appears that a coarse sugar may be procured from grapes at a trifling expense. In apples and pears, in the juice of liquorice, and in some other vegetable juices, sugar exists, but in a state of combination, which prevents it from assuming a crystallized form. In dried grapes, figs, &c. it is often seen as a superficial incrustation.

Animal sugar. Honey.

1792. *Honey* is also a variety of sugar containing a crystallizable and an uncrystallizable portion; the predominance of one or other of which gives to it its peculiar character; they may be partially separated by mixing the honey with alcohol, and pressing it in a linen bag; the liquid sugar being the most soluble, passes through, leaving a granular mass, which forms crystals when its solution in boiling alcohol is set aside. Honey also frequently contains wax, and a little acid matter.

Properties of sugar.

1793. Sugar is a white brittle substance of a pure sweet taste, soluble in its own weight of water at 60°. Boiling water dissolves a considerably larger quantity. This solution is called *sirup;* it is viscid, and furnishes crystals in the form of four and six-sided prisms, irregularly terminated. Sugar is soluble in alcohol, but much more sparingly so than in water.

1794. Nitric and sulphuric acids decompose sugar; the former converts it into oxalic acid; the latter evolves charcoal and produces water and acetous acid.

Action of alkalies.

1795. The alkalies dissolve sugar, and destroy its sweet taste, which re-appears if an acid be added. When, however, the alkalies are left for a long time in the contact of sugar they effect a more important change, becoming carbonated and converting the sugar into gum. From a solution of sugar in lime-water, Mr Daniell obtained crystals of carbonate of lime and a portion of gum. The addition of phosphuret of lime to sirup produces an analogous change.‡

Of protoxide of lead.

1796. When protoxide of lead is digested with sugar and water, a portion is dissolved and afterwards separates in the form of a white insipid powder (*saccharate of lead,*) insoluble in water, and composed, according to Berzelius, of

Sugar	41,74
Oxide of lead	58,26
	100,00

Action of caloric.

1797. When sugar is exposed to heat it fuses, becomes brown, evolves a little water, and is resolved into new arrangements of its component elements. If suddenly elevated to a temperature of about 500°, it bursts into flame.

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* See Chaptal on the manufacture of sugar in France, Phil. Mag. xlvii. 331.

† Nicholson's Journal, xxi. 356.

‡ Journal of Science and the Arts, vi. 32.

Composition.

1798. According to Lavoisier, sugar is composed of 64 oxygen, 28 carbon and 8 hydrogen: Gay-Lussac, Thenard and Berzelius have analyzed it by combustion with chlorate of potassa, and Dr Prout and Dr Ure by distillation with oxide of copper. The results of the analysis by different chemists are given below.*

On comparing the results of the analysis of sugar by different persons, the principal deviation appears to exist in those of Dr Prout, which indicate less charcoal and more oxygen than the rest. If reduced to atomic proportions, his experiments (respecting which some details are given in the Annals of Philosophy, N. S. iv.) point out the following as the composition of sugar:

Charcoal	5 atoms	30	40,00
Oxygen	5 ditto	40	53,34
Hydrogen	5 ditto	5	6,66
		75	100,

The atomic proportions, approaching most nearly to the other results, are

Charcoal	6 atoms	36	44,44
Oxygen	5 ditto	40	49,38
Hydrogen	5 ditto	5	6,18
		81	100.

If deduced from the compound of sugar with oxide of lead, on the supposition that this compound consists of an atom of each ingredient, the constitution of sugar will agree precisely with the latter statement, a coincidence which strengthens the probability that it consists of 6 atoms of charcoal, 5 of oxygen, and 5 of hydrogen, and that 81 is its true representative number. H. 2. 185.

Manna.

1799. *Manna* is an exudation from the *Fraxinus Ornus*, a species of ash, growing in Sicily and Calabria. It has a sweet and somewhat nauseous taste, and is used in medicine as a mild aperient. It is very soluble in water, and more soluble in alcohol than cane sugar, the latter solution deposits it in the form of a white spongy mass. Digested in nitric acid, it yields both oxalic and saclatic acids. Its solution in water does not appear susceptible of vinous fermentation.

	Gay-Lussac.	Berzelius.	Prout.	Ure.
* Carbon	42,47	44,200	39,99	43,38
Oxygen	50,63	49,015	53,33	50,33
Hydrogen	6,90	6,785	6,66	6,29
	100.†	100.	100.	100.

† Or of carbon	42,47
Oxygen and hydrogen in the same proportion as water	57,53
	100.

SECTION IV. *Starch.*

1800. STARCH, or *Fecula*, may be separated from a variety of vegetable substances; it is contained in the esculent grains, and in many roots. The process for obtaining it consists in diffusing the powdered grain or the rasped root in cold water, which becomes white and turbid; the grosser parts may be separated by a strainer and the liquor which passes deposits the starch, which is to be washed in cold water and dried in a gentle heat.

Process for obtaining starch.

1801. The common process for obtaining the starch of wheat consists in steeping the grain in water till it becomes soft; it is then put into coarse linen bags, which are pressed in vats of water: a milky juice exudes, and the starch falls to the bottom of the vat. The supernatant liquor undergoes a slight fermentation, and a portion of alcohol and a little vinegar is formed, which dissolves some impurities in the deposited starch; it is then collected, washed, and dried in a moderate heat, during which it splits into the columnar fragments which we meet with in commerce, and which are generally rendered slightly blue by a little smalt.

Analysis.

1802. From the analysis of Dr Pearson we learn that 100 parts of the fresh potato root, deprived of skin, afford

Water	68	to	72
Meal	32	,,	28
	100		100

The meal is composed of three distinct substances

Fecula	15	to	17
Fibrous matter	8	,,	9
Extract or mucilage	5	,,	6
	28		32*

Of rice, starch constitutes, according to Braconnot, from 83 to 85 per cent.†

Properties of starch.

1803. Pure starch is a white substance, insoluble in cold water, but readily soluble at a temperature between 160° and 180°. Its solution is gelatinous, becomes mouldy and sour by exposure to air, and by careful evaporation yields a substance resembling gum in appearance, which is a compound of starch and water.

Insoluble in alcohol, &c.

Precipitates oxide of lead.

Starch is insoluble in alcohol and in ether, and occasions no precipitate in the greater number of metallic solutions; in solution of subacetate of lead, however, it occasions a copious precipitate. The most characteristic property of starch is that of forming a blue compound with iodine; it may be obtain-

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* *Repertory of Arts*, iii. 383. See also analysis of several varieties of potato in *Ann. Philos.* v. 39.

† Ann. de Chim. et Phys. iv. 383.

Forms a blue with iodine.

ed by adding an aqueous solution of iodine to a dilute solution of starch.

Soluble in acids.

Sulphuric and nitric acids dissolve starch, and slowly decompose it, or resolve it into new compounds. Dilute nitric acid dissolves it without decomposition, forming a greenish solution, which deposits starch upon the addition of alcohol. It is slowly soluble in muriatic acid, and insoluble in acetic acid.

Unites to potassa.

Potassa, triturated with starch, forms a compound which is soluble in water.

Precipitated by tannin.

Infusion of galls occasions a precipitate in the solutions of starch, which re-dissolves by heating the liquid to 120°. This property Dr Thomson considers as characteristic of starch.

1804. The change of starch into sugar is always observed during the germination of seeds, and in the process of *malting* a similar conversion is effected.

Malt.

Malt is barley which has been made to germinate to a certain extent. after which the process is stopped by heat. The barley is steeped in cold water, and is then made into a heap or *couch*, upon the maltfloor: here it absorbs oxygen and evolves carbonic acid; its temperature augments, and then it is occasionally turned to prevent its becoming too warm. In this process the radicle lengthens, and the plume, called by the maltsters the *acrospire*, elongates; and when it has nearly reached the opposite extremity of the seed, its further growth is arrested by drying at a temperature slowly elevated to 150° or more. The malt is then cleansed of the rootlets.

Hordein.

1805. Proust has discovered in barley, besides the ingredients of wheat, a peculiar substance, nearly resembling saw-dust in its external characters, to which he has given the name of *hordein*. This substance may be separated from starch by the action of hot water, in which it is quite insoluble. During the process of malting, its proportion is considerably diminished, and it appears to be partly converted into sugar, or into starch, as will appear from the comparative analysis of malted and unmalted barley given below.*

1806. It appears, then, that the formation of malt consists in the increase of gum, sugar, and starch, and the diminution of gluten and hordein. The starch, that remains after malting, is found changed in its properties; for it does not as before yield a viscid paste, capable of gelatinizing on cooling.

The loss of weight, sustained by grain in malting, which Proust states at one-third, Dr Thomson asserts is greatly overrated, and that it did not on an average of 50 processes, carried on under his inspection, exceed one-fifth. The hordein of

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	In 100 parts of barley.	In 100 parts of malt.
* Resin	1	1
Gum	4	15
Sugar	5	15
Gluten	3	1
Starch	32	56
Hordein	55	12 H. 2. 242

Proust, he considers as starch under some modification, which is changed, by malting, partly into true starch, and partly into sugar. H. 2. 243.

Conversion of starch into sugar by sulphuric acid.

1807. Another mode of converting starch into sugar was discovered by M. Kirchoff; it consists in boiling it with very dilute sulphuric acid. A pound of starch may be digested in six or eight pints of distilled water, rendered slightly acid by two or three drachms of sulphuric acid. The mixture should be simmered for a few days, fresh portions of water being occasionally added to compensate for the loss by evaporation. After this process the acid is saturated by a proper proportion of chalk, and the mixture filtered and evaporated to the consistence of sirup; its taste is sweet, and, by purification in the usual way, it affords crystallized sugar. M. M. de la Rive and Saussure have shown that the contact of air is unnecessary in the above process; that no part of the acid is decomposed, no gas evolved, and that the sugar obtained exceeds by about one-tenth, the original weight of the starch. M. de Saussure, therefore, concludes that the conversion of starch into sugar depends upon the solidification of water, a conclusion strengthened by the following comparative analysis.—THOMSON's *Annals*, Vol. ii.

Analysis of starch.

	100 Parts of Starch contain	100 Parts of Starch Sugar contain
Carbon	45,39	37,29
Oxygen	48,31	55,87
Hydrogen	5,90	6,84
Nitrogen	0,40	0,00
	100,00	100,00

1808. This analysis of starch is somewhat at variance with that given by Gay-Lussac; indeed the small portion of nitrogen cannot be considered as an essential component. Berzelius has given the following as the component parts of starch.—THOMSON's *Annals*, Vol. v.

Carbon	43,481
Oxygen	48,455
Hydrogen	7,064
	100,000

Amyline.

1809. *Amyline* (called *amydine* by Saussure) is intermediate between gum and starch. It is soluble in boiling water, and the solution yields by evaporation a pale semitransparent brittle substance, insoluble in alcohol, but soluble in ten times its weight of cold water, and to any amount in water at 144°. The solution is coagulated into a white paste by sub-acetate of lead. When treated with iodine, it assumes a blue colour. It is precipitated by barytic water, but not by fixed alkalies, by lime water, nor by infusion of galls. H. 2. 246.

British gum.

1810. When starch is exposed to a temperature between 600° and 700° it swells, and exhales a peculiar smell; it becomes of a brown colour, and in that state is employed by calico-printers under the name of *British gum*. It is soluble in cold water, and does not form a blue compound with iodine. Vauquelin found it to differ from gum in affording oxalic instead of mucous acid, when treated with nitric acid.

Equivalent number.

1811. The equivalent of starch, if deduced from its ultimate analysis would approach very closely to that of sugar. It is probable, indeed, that in this, as well as in other instances of vegetable compounds, the difference consists merely in the manner in which the elementary atoms are arranged; a view of the subject, with which the conversion of starch into sugar, by processes not attended with the evolution of any gaseous products, is perfectly consistent. Berzelius investigated the equivalent of starch, by examining the composition of the insoluble *amylate of lead*, formed by mixing a boiling solution of potato starch with one of sub-nitrate of lead.[*] This he found to consist of 72 parts of starch + 28 of oxide of lead; and, reasoning from its composition, he infers that starch must be constituted, either of 6 atoms of oxygen + 7 of carbon + 13 of hydrogen, or of 18 atoms of oxygen + 21 of carbon + 39 of hydrogen. In this case the same agreement does not exist between the number deducible from ultimate analysis and from a compound of the entire substance with oxide of lead, as in the instance of sugar; for the equivalent, most consistent with the first supposition, would be not less than 103; whereas that for sugar is only 81. In this, as in various other cases, where the constitution of organic substances is concerned, it is better to wait for the further progress of science, than to rest satisfied with equivalent numbers, which are not supported by the concurrence of different methods of investigation. H. 2. 248.

Other varieties.

1812. Besides the starch of the cerealia and potatos, the following varieties of this substance are also met with.

i. *Arrow-root*, the fecula of the *Marantha Arundinacea*.

ii. *Sago*, extracted from the pith of several species of palm, growing in the East India islands.

iii. *Tapioca* and *Cassava*, prepared from an American plant, the *Iatropha Manihat*.

iv. *Salop*, obtained from the roots of several species of *Orchis*.

Starchy lignin.

1813. *Starchy lignin*—When the residue of the spontaneous decomposition of starch has been washed successively with cold and hot water, with alcohol, and with diluted sulphuric acid, an alkaline ley, containing $\frac{1}{12}$th its weight of potassa, still takes up a further portion. From this solution, diluted sulphuric acid precipitates a light brown combustible substance having the appearance of jet. It gives a blue colour to the aqueous solution of iodine, a property which, together with its solubility in a weak alkaline liquor, distinguishes it from common lignin. (1838.) It is not impossible, however, that the effect may depend on the presence of a small quantity of starch. H. 2. 246.

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[*] Ann. of Phil. v. 272.

SECTION V. *Gluten.*

1814. GLUTEN may be obtained from wheat-flour, by forming it into a paste and washing it under a small stream of water. The starch is thus washed away, and a tough elastic substance remains, which is gluten.

Properties. Its colour is grey, and, when dried, it becomes brown and brittle. It is nearly insoluble in water and in ether. When allowed to putrefy it exhales an offensive odour, and when submitted to destructive distillation, it furnishes ammonia, a circumstance in which it resembles animal products. Most of the acids and the alkalies dissolve it.

1815. Gluten is an essential ingredient in wheat-flour, and contributes much to its nutritive quality; and gives considerable tenacity to its paste.

1816. A substance, much resembling gluten, has been found in the juices of certain vegetables, especially in those which are milky and coagulable by acids. It is contained in the sap of the house-leek, of the cabbage, and most of the cruciform plants. Submitted to destructive distillation, it affords ammonia, and is in other respects similar to the animal principle, called albumen; hence it has been termed *vegetable albumen* Vegetable albumen.

1817. *Caoutchouc* and *Bird-lime* may also be considered as allied to gluten. Bird-lime. These substances are insoluble in water and in alcohol, but they are soluble in pure sulphuric ether. Caoutchouc is highly inflammable, burning with a bright flame which throws off much charcoal. When heated it softens, and is in that state soluble in some of the fixed oils. It is said to dissolve easily in oil of cajeput. These solutions are sometimes used as varnishes, but with the exception of that in ether, they remain clammy.

1818. The principles which have now been adverted to, viz. sugar, starch, gum or mucilage, and gluten, constitute the principal nutritive ingredients in most of the esculent vegetables. Wheat grown in Great Britain contains from 18 to 24 per cent. of gluten, the remainder being principally starch. The wheat of the south of Europe generally contains a larger quantity of gluten, and is therefore more excellent for the manufacture of macaroni, vermicelli, and other preparations requiring glutinous paste. The excess of gluten in wheat-flour compared with other grain, renders it peculiarly fit for making bread; for the carbonic acid, extricated during the fermentation of the paste, is retained in consequence of its adhesiveness, and forms a spongy and light loaf.*

1819. From the experiments of M. Taddei, an Italian chemist, it appears that the gluten of wheat may be decomposed into two principles, one of which he has distinguished by the name of *Gliadine*, from γλια gluten,) the other, of *Zimome* (from ζυμη, a ferment.) To separate them, fresh gluten must be kneaded with repeated portions of alcohol, as long as that fluid becomes milky by dilution with water. The alcohol dissolves the gliadine and leaves the zimome. Gliadine.

By evaporating the alcoholic solution, gliadine is obtained, forming a brittle straw-yellow, slightly transparent substance, with a weak smell resembling that of the honey-comb, and when gently heated, emitting an odour similar to that of boiled apples. In the mouth, it becomes adhesive, and has a sweetish and balsamic taste. It is pretty soluble in boiling alcohol, but the greater part precipitates as the alcohol cools. It softens, but does not dissolve in cold water. Its alcoholic solution becomes milky on adding water, and is precipitated, in white flocks by alkaline carbonates. Dry gliadine dissolves in caustic alkalies and acids. It swells on burning coals, and then contracts like animal matter. It burns with a bright flame, and leaves a portion of charcoal which is difficult to be incinerated.

1820. *Zimome* is obtained pure by boiling gluten in alcohol, or by digesting it in that fluid till it ceases to give out gliadine. There remains a shapeless mass, which is hard, tough, destitute of cohesion, and of an ash-white colour. After being washed with water, it recovers part of its viscosity; and becomes brown when left in contact with air. It is specifically heavier than water. It does not ferment like gluten, but putrefies, exhaling a fetid urinous odour. At a boiling temperature it is soluble in vinegar and in the mineral acids. It combines with potassa, and forms a kind of soap. Lime-water, and solutions of alkaline carbonates harden it, and give it a new appearance. It inflames when thrown on red hot coals, and emits an odour similar to that of burning hair or hoofs.† Zimome.

M. Taddei has since discovered that powdered guaiacum is a test of the presence of zimome. When well kneaded with good wheat flour and a little water, the guaiacum becomes of a very fine blue colour. Starch does not evolve this colour, and bad Test of.

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* A hundred parts of barley contain upon an average 80 parts of starch, 6 of gluten, and 7 of sugar, the remaining 7 parts being husk. From 100 parts of rye Sir Humphry Davy obtained 61 parts of starch and 5 of gluten From 100 parts of oats he procured 59 of starch, 6 of gluten, and 2 of sugar. 100 parts of peas afforded about 50 of starch, 3 of sugar, 4 of gluten, and a small portion of extractive matter. 100 parts of potatos yield, upon an average, 20 parts of starch; they may be considered in general as containing from one-fourth to one-fifth of their weight of nutritive matter. The turnip, carrot, and parsnip, chiefly contain sugar and mucilage: 1000 parts of common turnips give about 34 of sugar, and 7 of mucilage; 1000 parts of carrots furnish about 95 of sugar, and 3 of mucilage; and the same quantity of parsnips afford 90 of sugar and 9 of mucilage. The loss of weight in the above cases is referable to water, and inert vegetable matter possessed of the properties of woody fibre.

† Ann. of Philos. xv. 390, xvi. 88.

flour in only a very small degree. But when guaiacum is worked up with gluten, and, still better with pure zimome, the colour instantly appears, and is a most superb blue. Guaiacum, however, does not become at all coloured by zimome, unless the contact of oxygen be allowed. The powder of guaiacum is therefore, a re-agent, capable of detecting the injurious alteration which flour sometimes undergoes by the spontaneous destruction of its gluten, and also of ascertaining in a general way the proportion of that principle.* H.

SECTION VI. *Extractive matter and Lignin.*

1821. THE term *extract*, or *extractive principle* has been applied to a peculiar principle which is supposed to form the basis of all the vegetable extracts which are generally made by digesting vegetable substances in water, and evaporating the solution to a solid consistence.

1822. The existence of a distinct principle, under this name has been doubted by M. Thenard, Dr Bostock and Dr Ure; and it is not improbable that future discoveries may resolve it into other known bodies.

Properties.

1823. It is said to possess the following properties. It is soluble in water, and the solution is of a brown colour. It is insoluble in ether, but it is soluble in alcohol containing a small portion of water. By repeated solutions and evaporations it may be rendered scarcely soluble in water. Solutions of chlorine, of many of the acids, and of most of the metallic oxides, occasion precipitates in the aqueous solution of extractive.

1824. The following substances may be considered under this head, though many of them are obviously widely different from extractive matter.

Ulmin.

1825. *Ulmin.*—This substance was first noticed by Klaproth, spontaneously exuding from the elm. From the observations of Berzelius, it exists in the bark of many other trees, and may be obtained by digestion in alcohol and cold water; the action of hot water afterwards dissolves the ulmin.—THOMSON'S *Annals*, Vol. ii.

Characters.

Ulmin is of a dark brown colour, with scarcely any taste or smell. It is sparingly soluble in water and in alcohol, but readily soluble in a weak solution of carbonate of potassa. Very few of the metallic salts occasion a precipitate in its solution. The exudation from the elm is generally combined with carbonate of potassa, and is therefore readily soluble in water. From late experiments Dœbereiner considers it probable that ulmin consists of an atom of oxide of carbon, and an atom of water.†

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* Quarterly Journal, viii. 377.

† Quart. Journal, ix. 353.

Polychroite.

1826. *Polychroite.* This term has been applied to the extract of saffron.* It is of a deep yellow colour, deliquescent, readily soluble in water and in alcohol, but insoluble in pure sulphuric ether. Exposure to the solar rays soon destroys the colour of its aqueous solution. Sulphuric acid renders it blue, and nitric acid green : solutions of lime and baryta produce yellow and red precipitates ; subacetate of lead throws down a deep yellow precipitate, and nitrate of mercury separates a red powder.

Hematin.

1827. *Hematin.* This peculiar substance was first recognised by Chevreul in the colouring matter of *log-wood.*† It may be obtained by digesting log-wood in water of the temperature of 125°. Filter, evaporate carefully to dryness, and digest the residue for 24 hours in alcohol of the specific gravity of ,837. Filter the alcohol; concentrate the solution by evaporation, add a portion of water, evaporate a little further, and set the solution aside : crystals are deposited which, when washed with alcohol and dried, are pure hematin.

Hematin is of a reddish colour ; its taste is somewhat bitter, and its aqueous solution is yellow when cold, but orange-red at the temperature of boiling water. Sulphuric acid added to this solution renders it reddish yellow. The alkalies give it a purplish tint.

Bitter principle.

1828. *Bitter principle.* By evaporating an infusion of quassia, a substance is obtained of an intensely bitter taste, and of a brownish yellow colour, which is readily soluble in water and in alcohol. Nitrate of silver, and acetate of lead, are the only precipitants of its aqueous solution. It is probable that the same substance exists in other bitter vegetables, and Vauquelin has discovered it in the fruit of the *colocynth,* and in the root of *white briony.*‡

1829. By digesting indigo, silk, and a few other substances in nitric acid, an intensely bitter matter is formed, called by Welther the *yellow bitter principle.*|| Chevreul has rendered it probable that this is a compound of a peculiar vegetable principle with nitric acid. It is crystallizable, burns like gunpowder and detonates when struck with a hammer.

Picrotoxin.

1830. *Picrotoxin.* This is a bitter poisonous substance contained in the *Cocculus Indicus.* It may be obtained by the following process :—Add acetate of lead to a decoction of the berries, as long as any precipitate falls : filter, evaporate, and digest the extract in highly rectified alcohol ; evaporate to dryness, and agitate the remaining matter with a little water; the picrotoxin remains in the form of white prismatic crystals of a bitter taste.

Characters.

1831. Picrotoxin is difficultly soluble in water. Alcohol of the specific gravity of 810, dissolves one-third its weight. It

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* Ann. de Chim. lxxx.

† Ann. de Chim. lxxx. 1.

‡ Thomson's *System*, vol. iv.

† Ann. de Chim. xxix.

§ Ann. de Chim. xxix.

|| Ibid.

is soluble in weak solutions of the pure alkalies. It combines with the acids, and forms compounds, some of which are crystallizable, but they require further examination before we can venture to give this substance a place among the narcotic salifiable bases.[*]

Nicotin.

1832. *Nicotin.* This is a principle existing in tobacco. It was obtained by Vauquelin by the following process[†]: Evaporate the expressed juice to one-fourth its bulk; and, when cold, strain it through fine linen; evaporate nearly to dryness; digest the residue in alcohol; filter and evaporate to dryness; dissolve this again in alcohol, and again reduce it to a dry state. Dissolve the residue in water, and saturate the acid which it contains with weak solution of potassa, introduce the whole into a retort, and distil to dryness: re-dissolve, and again distil three or four times successively. The nicotin will thus pass into the receiver, dissolved in water, from which solution it may be obtained by very gradual evaporation.

Nicotin is colourless, acrid, soluble in water and in alcohol, volatile, and highly poisonous.

Asparagin.

1833. *Asparagin.*—M. M. Vauquelin and Robiquet obtained this substance in a crystalline form by evaporating the juice of asparagus. It has a cool and slightly nauseous taste, and when burned emits acrid vapours, and leaves no traces of alkali.[‡]

Sarcocoll.

1834. *Sarcocoll* exudes spontaneously from a plant called the *Penea Sarcocolla.* It is generally of a red, or yellow colour, and is soluble in alcohol and water, forming mucilaginous solutions. Tan causes its immediate precipitation.

Fungin.

1835. *Fungin.* This name has been given by Braconnot to a substance contained in the fleshy part of mushrooms.[§]

It is insoluble in water and in alcohol, and scarcely acted upon by the alkalies, or by dilute acids. It is the substance which remains after the mushroom has been deprived of every thing soluble in alcohol and in water.

Inulin.

1836. *Inulin.* The roots of elecampane, when boiled in water, furnish a decoction, which, on cooling, deposits a white powder, in many respects resembling starch. It, however, differs in several properties from that principle, and has hence been considered a peculiar vegetable substance.[||]

Emetin.

1837. *Emetin.* To obtain emetin, digest powdered ipecacuanha in alcohol, filter, evaporate carefully to dryness, and redissolve in cold water. To this solution add carbonate of baryta, filter, and again evaporate to dryness; digest this residuum in alcohol, and a solution is obtained, which by careful evaporation, affords a reddish-brown substance, soluble in alcohol and in water, and precipitable by sub-acetate of lead; its taste is acrid and bitter, and it is highly emetic.[¶]

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[*] Boullay, *Journal de Pharmacie*, v.

[†] Ann. de Chim. lxxi.

[‡] Ann. de Chim. iv.

[§] Ann. de Chim. lxxix.

[||] Thomson's *System*, vol. iv.

[¶] MM. Magendie and Pelletier, *Annales de Chimie et Physique*, Vol. iv.

Woody fibre.

1838. *Woody fibre.* The term *lignin* has been applied to the fibrous substance which remains, after digesting wood in water and in alcohol. It is insipid, and exposed to destructive distillation, affords a considerable quantity of vinegar tainted by empyreumatic oil, and containing a little ammonia. The charcoal which remains is light, brittle, shining, and easily incinerated. The relative quantity, yielded by different woods, has already been adverted to (625.)

Action of sulphuric acid on wood.

1839. We are indebted to M. Braconnot for some highly interesting experiments, relating to the action of sulphuric acid on wood.* In the course of these researches, he triturated 25 parts of hempen cloth with 34 of the acid; it acquired the consistency of mucilage, which, after 24 hours, was almost entirely soluble in water. The diluted liquor was saturated with chalk, filtered, and evaporated to the consistency of sirup; it deposited sulphate of lime, and was then further evaporated to dryness, when a substance, having the characters of gum, was obtained. In another experiment, 24 parts of lignin were reduced to gum by 34 of sulphuric acid; this acid mixture, diluted with water, and boiled for 10 hours, became sweet; the acid was then separated by chalk, and the liquor, on due evaporation, afforded a crystallizable sugar.

Moistened saw-dust, heated in a platinum crucible with its weight of caustic potassa, afforded a matter soluble in water, and which, upon the addition of an acid to neutralize the alkali, yielded a substance having the properties of *ulmin.*

Of air.

1840. The woody fibre by exposure to the atmosphere in a perfectly dry state, does not undergo any change. The action of the air upon it, however, when moistened, causes it to pass through various shades of colour, into a black mould. If the process be carried on in a confined portion of oxygen gas, carbonic acid is formed. When excluded from the air, even moist wood shows very little tendency to decomposition.

Composition.

1841. The atomic constitution of lignin, which agrees most nearly with its ultimate analysis is the following:

Carbon	7 atoms	42	53,86
Oxygen	4 "	32	41,02
Hydrogen	4 "	4	5,12
		78	100 H.2.256.

Suber.

1842. *Suber* or *Cork.* This is a light, soft, elastic, and combustible substance, burning with a bright flame and leaving a bulky charcoal. Its principal peculiarity is, that by digestion in nitric acid, it is converted into an orange-coloured mass, which furnishes to water a peculiar acid matter, which has been termed *suberic acid.* Chevreul has found in it resin, oil, and a peculiar matter which he calls *Cerin.*†

Cotton.

1843. *Cotton* is a downy substance found in the seed-pods of the different species of *gossypium.* It is insoluble in water and in dilute alakline and acid solutions. It combines with several of the metallic oxides, which are therefore used as intermedes, or *mordants*, in the art of dyeing. Acetate of alumina is principally employed for this purpose.

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* Ann. de Chim. et Phys. xii. 172.

† See Wax.

Medullin.

1844. *Medullin* is a term given by Dr. John to the pith of the sun-flower and some other plants; it is insipid, inodorous, insoluble in water and alcohol, and affords oxalic acid when treated by nitric acid; submitted to destructive distillation, the products abound in ammonia.

SECTION VII. *Tannin.*

Extraction.

1845. TANNIN, or the astringent principle, is contained in many vegetables. It may be procured by digesting bruised gall-nuts, grape-seeds, oak-bark, or catechu, in a small quantity of cold water. The solution affords, when evaporated, a substance of a brownish-yellow colour, extremely astringent, and soluble in water and in alcohol.

Artificial tannin.

The purest form of tannin appears to be that derived from bruised grape-seeds, but even here it is combined with other substances, from which it is perhaps scarcely separable, and among the numerous processes which have been devised for procuring pure tannin, there is none that answers the intended purpose. Mr. Brande recommends the following process as that by which he has obtained tannin of the greatest apparent purity. Digest powdered catechu in water at 33° or 34°, filter and boil the solution, which, on cooling, becomes slightly turbid, and is to be filtered again, and evaporated to dryness; cold water, applied as before, extracts nearly pure tannin.*

* The following process, practised by Tromsdorff, is described by Dr Thomson, as yielding tan of greater purity than any other method. Three parts of bruised galls were digested with 40 parts of water for three days, at the temperature of 66° Fahr., the mixture being frequently stirred. The whole was now placed on a linen strainer, the liquid set apart, and the residuum treated as before with 40 parts of water. Four different infusions were thus made, all of which were gently evaporated together to one-fourth their bulk in a porcelain basin. The liquid, being drained through a thick linen cloth, was further evaporated to the consistence of a jelly, and placed upon a flat porcelain dish near a stove till it became dry. The dry mass was digested with thrice its weight of *pure* alcohol; and this digestion was repeated three times, till the last portion of alcohol was found to be free from *gallic acid;* and to remove this acid effectually, the dry mass was digested, twice in succession, with alcohol, containing ten per cent. of water. The tan, however, was still considered as contaminated with extractive and mucilaginous matter. To get rid of these, the whole was dissolved in distilled water, and again evaporated to dryness. These solutions and evaporations were repeated several times, with the view of rendering the extract insoluble; but nothing insoluble was thus separated. The last solution, being left some time in a warm place, contracted a mouldy scum, which was removed. The liquid beneath it, being evaporated to dryness, left tan of considerable purity, but still containing sulphate of lime. To separate this, the tan was dissolved in water, and carbonate of potassa added as long as any precipitate fell. The liquid was then filtered and mixed with acetate of lead, which threw down a compound of oxide of lead and tan. This powder was washed and dried. and being diffused in water, a current of sulphuretted hydrogen was transmitted through it. The lead was thus thrown down in union with sulphur, while the tan dissolved in the water. The liquid, after being boiled, filtered, and evaporated to dryness, gave tan in a state of as great purity as can be obtained from nut-galls. H. 2. 266.

Properties. 1846. The most distinctive character of tannin is that of affording an insoluble precipitate when added to a solution of isinglass, or any other animal jelly. Hence infusion of tan is used as a test of the presence of gelatine, and, reciprocally, solution of gelatine may be used as a test of the presence of tan. The solution of gelatin, or jelly, may be prepared for the purpose of precipitating tan, by dissolving isinglass in water, in the proportion of ten grains to two ounces. The precipitate which has been called *Tanno-gelatine* consists of 54 jelly and 46 tan. An excess of the solution partly re-dissolves it.

Tanning. Upon this property the art of tanning depends, for which oak-bark is generally employed; the barks, however, of many other trees may occasionally be substituted.*

Union with other bodies. Metallic oxides. 1847. Tan forms a precipitate with solution of starch, with gluten and albumen, and with many of the metallic oxides. An account of the precipitates formed in metallic solutions by infusion of galls, will be found in the *Tables*: but these precipitates are very complex, and vary in composition.

1848. If the solution of tan, obtained as above-described from catechu, be added to acetate of lead, an insoluble *tannate of lead* falls, composed, according to Berzelius, of 100 tannin + 52 oxide of lead. Now, if we suppose that tannin forms definite compounds with the metallic oxides, in the manner of a vegetable acid, the number 215,3 will be its representative, as deduced from the above datum.

Artificial tan. 1849. Mr. Hatchett has shown that tan may be formed artificially by digesting charcoal in dilute nitric acid during several days; it is at length dissolved, and a reddish brown liquor is obtained, which furnishes, by careful evaporation, a brown glossy substance, amounting to about 120 parts from 100 of charcoal.

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* The following Table, drawn up by Sir Humphry Davy, exhibits the average quantity of tan contained in 480 lbs. of different barks:—*Agricultural Chemistry*, 4to. p. 79.

	lbs.
Average of entire bark of middle-sized Oak, cut in spring	29
———— of Spanish Chestnut	21†
———— of Leicester Willow, large size	33
———— of Elm	13
———— of Common Willow, large	11
———— of Ash	16
———— of Beech	10
———— of Horse Chestnut	9
———— of Sycamore	11
———— of Lombardy Poplar	15
———— of Birch	8
———— of Hazel	14
———— of Black Thorn	16
———— of Coppice Oak	32
———— of Oak cut in autumn	21
———— of Larch cut in autumn	8
White interior cortical layers of Oak-bark	72

† Chestnut wood has been found to contain twice as much tannin as the inner bark of the oak, and six-sevenths as much colouring matter as logwood. See Mr Sheldon's paper in *Amer. Jour. of Science*, 1. 312.

This *artificial tannin* appears to differ in one circumstance only from natural tannin, which is, that it resists the action of nitric acid, by which all the varieties of natural tannin are decomposed, though some are more capable of resisting its action than others.

Artificial tannin has a bitterish astringent taste, is soluble in water and alcohol, and forms an insoluble precipitate in solutions of animal gelatine, the precipitate consisting, according to Mr Hatchett, of 36 tannin + 64 gelatine.

Action of acids.

Muriatic and sulphuric acids occasion brown precipitates, in solution of artificial tan, which are soluble in hot water. It combines with the alkalies, and forms a precipitate of difficult solubility in aqueous solutions of lime, baryta, and strontia, and in most metallic solutions; these precipitates are of a brown colour.

Dyeing.

1850. A variety of artificial tan is formed by digesting camphor and resins in sulphuric acid till the liquor becomes black, and on being poured into water, deposits a black powder, which, by digestion in alcohol, furnishes a brown matter, soluble in water, and forming an insoluble precipitate with gelatine.*

SECTION VIII. *Colouring Matter*

Dyeing.

1851. THE colouring matter of vegetables appears to reside in several of their principles, and is therefore very differently acted on by solvents. Its extraction, and transfer to different substances, constitutes the *art of Dyeing*.

1852. Different materials not only possess very different attractions for dye stuffs, but they absorb the colouring matter in very different proportions. Wool appears in this respect to have the strongest attraction for colouring substances: silk comes next to it; then cotton; and, lastly, hemp and flax.

1853. Colours have been divided by Dr Bancroft, in his work on *permanent Colours*, into *substantive* and *adjective*. The former communicate colour without the intervention of any other substance. They have an attraction for the fibre of cloth or linen, and are permanently retained. The latter require the intervention of some body, possessed of a joint attraction for the colouring material and stuff to be dyed. The substance capable of thus fixing the colour, has been called a *basis*, or *mordant*.

Mordants.

1854. The mordants most frequently applied are *acetate of alumina*, *sulphate* or *acetate of iron*, and *muriate of tin*. The substance to be dyed is first impregnated with the mordant, and then passed through a solution of the colouring matter, which is thus fixed in the fibre, and its tint is either modified or exalted by the operation.

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* Hatchett, *Phil. Trans.* 1805, 1806.

The following are the modes of producing some of the principal colours.

Black. 1855. *Black* is produced by astringents and salts of iron, and if intended to be deep and perfect, the cloth should previously be dyed blue with indigo. The stuff is first soaked in a bath of galls, then rinced, and passed repeatedly through a solution of sulphate of iron in infusion of logwood; exposure to air deepens the colour, which at first has a purplish tint. Logwood tends considerably to improve the black, and prevents its acquiring a rusty or brown hue. Sometimes madder is used for the same purpose. Silk is dyed black nearly in the same way, but it requires a much larger relative proportion of galls, and the operation must be frequently repeated. It is difficult to give a good and permanent black to calico; in this process, acetate of iron, galls, and madder are generally used, and the colour is rendered more durable by previously steeping the goods in a weak solution of glue.

Grey. *Grey* is produced by the same operations as black, but the materials are used in a very dilute state.

Blue. 1856. *Blue* is chiefly derived from *indigo*, a substance produced by fermenting the leaves of several species of the *indigofera*, a plant abundantly cultivated in South America and in the East Indies.

Indigo. 1857. *Indigo* is a substance of a deep blue colour, containing about 50 *per cent.* of pure colouring matter, which is perfectly insoluble in water; when heated it sublimes in the form of a blue smoke, which on condensation, forms acicular crystals. It is soluble in concentrated sulphuric acid. This solution is usually called *Saxon* or *liquid blue*, and is used as a substantive colour for dyeing cloth and silk. Substances which powerfully attract oxygen render indigo green, and by exposure to air, it again acquires a blue colour. In this green state indigo is soluble in the alkalies, and the solution is commonly employed for dyeing calico. A bath for this purpose may be made by mixing one part of indigo, two parts of sulphate of iron, and two of lime, in a sufficient quantity of water: in this case the sulphate of iron is decomposed by a portion of the lime. The protoxide of iron thus produced becomes peroxidized at the expense of the indigo, which is rendered green and soluble in the alkaline liquor; cotton steeped in this solution acquires a green colour, which by exposure to air, and washing in water acidulated with sulphuric acid, becomes a permanent blue.

A little iron or zinc thrown into diluted sulphate of indigo, changes or destroys the colour in consequence of the evolution of hydrogen; the colour is also quickly impaired and destroyed by chlorine.

Analysis of indigo. 1858. The analysis of indigo, to ascertain the proportion of colouring matter, which varies much in different samples, may be performed by the successive action of water, alcohol, and muriatic acid, (Chevreul, *Ann. de Chim.* lxvi. 20.) 100 parts of Guatimala indigo, thus treated, afforded

To water . .	Green matter combined with ammonia	12
	Deoxidized indigo	
	Extract	
	Gum	
To Alcohol.	Green matter	30
	Resin	
	A trace of indigo	
To Muriatic Acid.	Red resin	6
	Carbonate of lime	2
	Oxide of Iron	2
	Alumina	
Residue .	Silica	3
	Pure indigo	45
		100*

Action of nitric acid.

1859. There appears to be a certain stage of oxygenizement in indigo, which is essential to the developement of its blue colour, and any proportion of oxygen, either exceeding or falling short of this, is equally destructive of its perfect hue. Thus diluted nitric acid dissolves indigo, but the solution is yellow, and the indigo is decomposed. A thin layer of resinous matter appears floating in the solution. If this be removed, and the solution, after evaporation to the consistence of honey, be re-dissolved in hot water, filtered, and mixed with a solution of potassa, yellow crystals appear, which consist of the bitter principle united with potassa. These crystals, being wrapped up in paper and struck with a hammer, detonate and emit a purple light. If, to a drachm or two of finely powdered indigo, we add an ounce measure of fuming nitrous acid, the mixture presently becomes hot, nitrous gas is evolved, a stream of sparks arises, from it, and finally the whole bursts into flame. When the action of the nitric acid is moderated by adding an equal bulk of water, and the mixture, after being digested for some days, is evaporated to dryness, the residuum is soluble in water, and contains a small proportion of oxalic acid, with a considerable quantity of artificial tan. Benzoic acid may also be obtained from the dry mass by sublimation. It appears then that by the action of nitric acid on indigo, there are generated oxalic and benzoic acids, tan, and the bitter principle. H. 261.

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* In order to find the value of any sample of indigo, Mr Dalton directs to take one grain, carefully weighed from a mass finely pulverized, put this into a wine glass, and drop two or three grains of concentrated sulphuric acid upon it. Having triturated them well, pour in water, and transfer the coloured liquid into a tall cylindrical jar, about one inch inside diameter. When the mixture is diluted with water, so as to show the flame of a candle through it, mix the liquid solution of chloride of lime with it, agitating it slowly, and never putting in any more until the smell of the preceding portion has vanished. The liquid soon becomes transparent, and of a beautiful greenish-yellow appearance. After the dross has subsided, the clear liquid may be poured off, and a little more water put into the sediment with a few drops of chloride of lime and a drop of dilute sulphuric acid; if more yellow liquid is produced, it arises from particles of indigo which have escaped the action of the chloride before, and must be added to the rest. The value of the indigo Mr. Dalton considers to be in proportion to the quantity of real chloride of lime necessary to destroy its colour. See *Manchester Memoirs* N. S. iv. 437.

1860. Chlorine destroys its colour, and the same quantity of free chlorine discolours always the same quantity of indigo. Hence a solution of indigo in sulphuric acid has been employed for measuring the strength of solutions of chlorine and of chloride of lime, in order to regulate their application to the process of bleaching.* Effect of chlorine.

1861. To obtain indigo of sufficient purity for experiment, the yellow solution of de-oxidized indigo by lime, which forms the dyer's blue vat, may be agitated in contact with air, which will revive the indigo, and precipitate it purified to a certain degree. The precipitate may be digested in dilute muriatic acid, which will remove a little iron and carbonate of lime. It is then to be washed with distilled water, and dried.† To obtain pure indigo.

Indigo may be purified more completely by sublimation. About ten grains of purified indigo, in lumps of about 1 grain, may be placed in a shallow metallic capsule of about 3 inches diameter, covered with a similar capsule, the concave sides of both being placed inwards, and at a distance not exceeding three-eighths of an inch in the middle. Mr Crum used two platinum crucible covers, but similarly shaped vessels of other metals would probably answer equally well. The lower capsule is to be heated by a spirit lamp; and when a hissing noise, which at first attends the process, has nearly ceased, the lamp is to be withdrawn, and the apparatus allowed to cool. On removing the cover, the sublimed indigo is found planted on its inner surface, forming long flat needles, in quantity equal to 18 or 20 per cent. of the original weight, and of a brilliant and intense copper colour. The colour, however, varies with the circumstances under which the crystals are observed. The specific gravity of the sublimate is 1,3.

1862. Sublimed indigo is fusible and volatile at a heat of about 550° Fahrenheit, leaving no residue when heated in open vessels. Its vapour is transparent and of a beautiful violet colour, differing from that of iodine by a shade of red. The melting point of indigo, that at which it sublimes, and that at which it is decomposed, appear to be remarkably near each other. Boiling oil of turpentine dissolves enough of purified indigo to acquire the same fine violet colour as its vapour, but deposits it again on cooling. Sublimed indigo.

By the ignition of sublimed indigo with peroxide of copper in green glass tubes, its analysis gave Analysis.

Carbon . . .	73,22
Azote . . .	11,26
Oxygen . . .	12,60
Hydrogen . . .	2,92
	100,00

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* For a description of an instrument for this purpose contrived by M Gay Lussac, see *Ann. de Chim. et Phys.* for June 1824.

† See an interesting paper, containing "Experiments and Observations on Indigo, and on certain substances which are produced from it by means of Sulphuric Acid," by Mr Walter Crum of Glasgow, in the Annals of Philosophy, N. S. v. 81.

These numbers correspond very nearly to

Carbon	16 atoms	= 96	or	73,84
Azote	1 ditto	= 14	or	10,77
Oxygen	2 ditto	= 16	or	12,31
Hydrogen	4 ditto	= 4	or	3,08
Equivalent number		130		100,[*] H. 2.672.

Cerulin and Phenicin.

1863. By the action of sulphuric acid on indigo two new substances are obtained termed by Mr Crum *Cerulin* and *Phenicin*. To prepare the former, the indigo is digested in the acid, the mixture is dissolved in a large quantity of sulphuric acid, and the filtered solution is precipitated by potassa. The precipitate consists of *cerulin*, in combination with the sulphate of potassa and has been called *Ceruleo-sulphate of potassa*. It requires about 140 parts of water for its solution, and forms a very deep blue coloured liquid. In its property of forming insoluble compounds with neutral salts, cerulin is analogous to tan. From its ultimate analysis it appears to consist of 1 atom of indigo + 4 atoms of water.

Phenicin how procured.

1864. *Phenicin* is procured by stopping the action of the acid on indigo before it is converted into cerulin; diluting, filtering and washing the mixture with water, when it becomes of a bottle green colour: muriate of potassa is added to the blue washings which are finally obtained, when the phenicin is precipitated of a fine reddish purple colour. It is soluble in water, and in alcohol, forming blue-coloured solutions, and is easily converted into cerulin by the action of water. From its ultimate analysis Mr Crum is disposed to consider phenicin as constituted of 1 indigo + 2 water.

Lakes.

1865. The colouring matter of vegetables, besides being capable of fixation on cloth, may be obtained in a dry form, in combination with a base only. Thus, if to a decoction or infusion of madder in water, a solution of sulphate of alumina be added, the colouring matter is precipitated in combination with the alumina, forming what is termed a *lake*. For obtaining this, the following process is given by Sir H. Englefield. Put two ounces of Dutch crop-madder into a calico bag, capable of holding three or four times that quantity. Pour on it a pint of distilled water, and triturate, in a mortar, as much as can be done, without destroying the bag. The water becomes loaded with colouring matter, and is opaque and muddy. Pour off this portion, and repeat the operation till no more colour is obtained, which will generally happen after the fifth or sixth affusion. Pour these several washings into an earthen or well-tinned copper pan; and apply heat till the liquor boils. Let it then be poured into a basin; and one ounce of alum, dissolved in a pint of water, be added, and mixed by stirring. Add an ounce and a half of saturated solution of sub-carbonate of potassa; a violent effervescence will ensue, and the colouring matter will be precipitated. Stir the mixture till cold, and wash repeatedly with boiling water. About half an ounce of lake will be obtained, containing two-fifths its weight of alumina.

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[*] Mr Crum objects, properly to the application of the term *indigogene*, applied by Brugnatelli to sublimed indigo, and denies the power, which has been ascribed to the sublimate, of amalgamating with mercury.

Other lakes may be obtained of different colours, by the substitution of different dyeing-woods; and from the infusion of cochineal, the beautiful pigment called Carmine is precipitated by means of a solution of tin. H. 2. 263.

1866. *Yellow.* There are several dyestuffs employed in the production of yellows. A decoction of *Weld* (*Reseda Luteola,*) with an aluminous mordant gives a good yellow, which is rendered more brilliant by tartar, and by permuriate of tin. Yellow.

The bark of the American oak (*Quercus Nigra,*) or *Quercitron bark,* also furnishes excellent yellows; it was first introduced into England by Dr Bancroft, who has fully and philosophically detailed its various applications.* The salts of alumina and of tin are the principal mordants employed both with wool and cotton.

Fustic wood, sumac, and *dyers' broom,* are also occasionally employed as sources of yellow colours.

1867. *Reds* are chiefly produced from *madder,* the prepared root of the *Rubia Tinctorum.* The colouring matter is fixed by an aluminous mordant, assisted by galls, but the process is very complex and circuitous. In Dr Bancroft's work above quoted (vol. ii.) are full details upon this subject; and a perspicuous abstract of them will be found in AIKIN's *Dictionary,* Art. DYEING. Reds.

Brazil wood, safflower, and *logwood* are occasionally employed as red or pink dye stuffs, but they only give fugitive colours.

1868. *Scarlet* is produced exclusively with the colouring matter of the *cochineal,* a small insect brought from Mexico, where it is found upon different species of the *Opuntia.* The nature of this colouring matter has been investigated by M. M. Pelletier and Caventou; it is united in the insect with a peculiar animal matter, fat, and some saline substances; they separated it by exposing a strong alcoholic tincture of cochineal to spontaneous evaporation; it deposited a crystalline matter, which was re-dissolved in alcohol and the solution mixed with its bulk of sulphuric ether; this caused it in a few days to deposit the pure colouring principle, which they call *Carminium:* Dr John has proposed for it the term *Coccinellin.* This substance is fusible at about 120°, very soluble in water, less so in alcohol, and insoluble in ether; the acids change its colour from purple to pale red or yellow: the alkalies render it violet; and its colour is impaired by most saline solutions. It readily combines with alumina, forming a beautiful *lake* or *carmine.* Scarlet.

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* Experimental Researches concerning the Philosophy of Permanent Colours, &c. London, 1813.

The colouring matter of cochineal is fixed upon wool by nitromuriate of tin and tartar, by which scarlets are produced and alum changes the scarlet to crimson. Cotton and linen are very rarely dyed with cochineal, for independent of its great expense the colours are little superior to those given by madder.

Buff. 1869. *Buff* and *Fawn Colour* are produced in a variety of ways. *Walnut-husks* and *Sumac*, with alum mordants, give durable colours of this description, which are rendered *Drab*, or *Grey*, by a very little iron.

Green. 1870. *Green* is obtained on woollen cloth, by passing it through the green indigo vat, and then dyeing it as for simple yellows, the relative proportion of the blue and yellow being adjusted to the intended intensity of the green. Silk is first dyed yellow, and afterwards blued with indigo. *Saxon green* is done by dyeing yellow upon a Saxon blue ground. A solution of verdigris in vinegar is sometimes used to produce a delicate green; pearlash is added before it is used, and the cotton previously impregnated with the alum mordant, is then passed through the mixture.[*]

Calico-printing. 1871. *Calico-printing* is a more refined and difficult branch of the art of dyeing. In this process adjective colours are almost always employed. The mordants, the principal of which are acetate of alumina, and acetate of iron, are first applied to the calico by means of wooden blocks or copper plates, upon which the requisite patterns are engraved. The stuff is then passed through the colouring bath, and afterwards exposed on the bleaching ground, or washed. The colour flies from those parts which have not received the mordant, and is permanently retained on those parts only to which the basis has been applied: variety of colours is produced by employing various mordants and different colouring materials.

White spots upon a dark ground are sometimes produced by covering the parts with wax, pipe-clay, or other materials, which prevent the contact of the colour; or citric acid, thickened with gum, is applied, like a mordant with a block or plate which prevents the retention of the colour. Sometimes the colour is discharged in places by the application of chlorine.[†]

SECTION IX. *Wax.*

1872. THIS principle exists in many plants; it may be obtained by bruising and boiling them in water; the wax separates and concretes on cooling.

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[*] Besides the above, an infinite variety of *compound colours* are formed, by mixtures of the simpler tints, and of the mordants; for practical details see Dr Bancroft's *Treatise*, and Berthollet *on Dyeing*.

[†] See Parkes' *Essays*, v. 1. and Bost. Jour. of Philos. iii

The berries of the *Myrica cerifera*, and the leaves and stem of the *Ceroxylon* afford considerable quantities of wax by this process.[*] The glossy varnish upon the upper surface of the leaves of many trees is of a similar nature, and though there are shades of difference, these varieties of wax possess the essential properties of that formed by the bee.

1873. Pure wax is colourless and insipid ; its specific gravity is about ,96 : it is insoluble in water, and fusible at a temperature of about 150° ; at a higher temperature it is converted into vapour, and at a red heat it burns in the contact of air with a bright flame. It is sparingly soluble in boiling alcohol and ether, and is deposited as the solutions cool. The fixed oils, when assisted by heat, readily dissolve it, and form a compound of variable consistency, which is the basis of *cerates* and *ointments*. Some of the volatile oils also dissolve wax, when aided by heat. It is soluble in the fixed alkalies, forming soapy compounds; but the acids scarcely act upon it; hence the advantage of *wax-lute* for the retention of corrosive vapours. Properties. Cerates.

1874. When bees'-wax, or myrtle-wax, are digested in boiling alcohol, they afford, according to Dr John, a soluble and insoluble portion ; he has called the former *cerin*, the latter *myricin*. Cerin is insoluble in water and in cold alcohol and ether, but dissolves in those liquids when heated. Myricin is insoluble, under all circumstances, in alcohol and ether. Cerin. Myricin.

The term *cerine* has been applied by Chevreul to a principle resembling wax which he separated from cork ; it is less fusible than wax, more soluble in alcohol, and partly converted into oxalic acid, by the action of nitric acid. Cerine.

Gay Lussac and Thenard, and Dr Ure, have analyzed yellow wax by combustion with peroxide of copper and deduced its elements to be

Carbon	81,784	80,69
Oxygen	5,544	7,94
Hydrogen	12,672	11,37
	100[†]	100[‡]

The atomic constitution, most consistent with these results is,

Carbon	13 atoms	78	80,41
Oxygen	1 atom	8	8,26
Hydrogen	11 atoms	11	11,33
		97	100.

But it is not improbable, as Dr Ure has remarked, that an atom more of hydrogen may exist in wax than has been discovered by analysis, and that it may consist of 12 atoms of olefiant gas + 1 atom of carbonic oxide. H. 2. 275.

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[*] Bostock, Nicholson's *Journal*, Vol. iv. Brande, *Phil. Trans.* 1811. Dana, in *Amer. Journal of Science*, i.

[†] Recherches, ii.

[‡] Phil. Trans. 1822.

SECTION X. *Fixed Oil.*

Emulsions.

1875. FIXED OIL is generally obtained by pressure from certain seeds, such as the almond, linseed, and many others and from the olive. The specific gravity of the fixed oils, is usually a little below that of water. They are viscid; insipid, or nearly so; and generally congeal at a temperature not so low as that required to freeze water. A few of them are solid at the ordinary temperature, and have been called *vegetable butters.* They are insoluble in water, but by the aid of mucilage may be diffused through it, forming *emulsions.* They are for the most part sparingly soluble in alcohol and ether, though castor-oil dissolves in any quantity in those fluids.*

1876. Olive oil is sometimes adulterated with that of certain seeds, which may be detected by the action of nitrate of mercury. For this purpose, 6 parts of mercury are dissolved without heat, in 7,5 parts of nitric acid, specific gravity 1,36; this solution, shaken with olive oil, becomes solid in a few hours; but if sophisticated with oil of grains, it does not solidify it.

Stearine.

Elaine.

1877. If oil, which has been congealed by cold, be submitted to pressure between folds of bibulous paper, a dry, concrete, fatty matter is obtained, which Chevreul has called *Stearine:* the paper absorbs a fluid matter, which does not congeal at a much lower temperature, and which, though it does not become rancid, acquires viscidity by exposure to air. This fluid part he has called *Elaine.* The relative proportions of these principles differ in the different oils.†—*Annales de Chimie,* Tom. xciii. xciv.—See *Animal Oils.*

M. Pictet's method of procuring elaine, consists in pouring upon oil a concentrated solution of caustic soda, stirring the mixture, heating it slightly to separate the elaine from the soap of the stearine, pouring it on a cloth, and then separating by decantation the elaine from the excess of alkaline solution.

1878. These oils cannot be volatilized without decomposition, which takes place at a temperature of about 600°, and water is copiously formed, attended by the separation of carbonaceous matter, which causes the oil to blacken and grow thick; a portion of acetic acid is also at the same time formed. If the vapour be collected, it is found acrid, sour, and empyreumatic; it was formerly employed in pharmacy, under the name of *philosopher's oil,* and as it was often obtained by steeping a brick in oil, and submitting it to distillation, it was also called *oil of bricks*. Passed through a red hot tube, the fixed oils furnish a very large proportion of carburetted hydrogen gas; and when burned in the wicks of lamps they suffer a similar decomposition, and water and carbonic acid are the products of their combustion.

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* Brande, *Phil. Transactions,* 1811.

† For the purpose of lubricating delicate wheel-work, as in chronometers, clocks, &c. it is important that oil should be free from every kind of acid, or of mucilage, that it should in fact be pure elaine, without any trace of stearine. In order to extract the elaine from fixed oils M. Chevreul treats it in a matrass, with 7 or 8 times its weight of alcohol nearly boiling, decanting the liquid, and exposing it to cold. The stearine will then separate in the form of a crystallized precipitate. The alcoholic solution must then be evaporated to the fifth of its volume, and the remainder will be elaine, which ought to be colourless, insipid, almost without smell, without any action on the infusion of turnsole, having the consistence of white olive oil, and coagulable with difficulty. *Edin. Jour.*

Oil of bricks.

1879. The greater number of the fixed oils undergo little other change by exposure to air than that of becoming somewhat more viscid, and acquiring a degree of rancidity. In this state they contain free acid, and redden vegetable blues. Some few, such as linseed, and nut-oil, and the oils of the poppy and hemp-seed, become covered with a pellicle, and when thinly spread upon a surface, instead of remaining greasy, become hard and resinous; these are termed *drying oils*, and their drying quality is much improved by boiling them upon a small quantity of litharge.

Drying oils.

1880. The drying oils, and especially nut-oil, form the basis of *printer's ink*, the history of which will be found in LEWIS's *Phil. Commerce of the Arts*. The oil is heated and set fire to, and after having been suffered to burn for half an hour is extinguished, and boiled till it acquires a due consistency; in this state it is called *Varnish*, and is viscid, tenacious, and easily miscible with fresh oil, or with oil of turpentine, by which it is properly thinned, and afterwards mixed with about one-eighth part of lamp-black.

Printers' ink.

1881. Nitric acid acts with great energy on the fixed oils. In a small proportion, its chief effect is to render them thicker. When distilled together with a larger proportion of acid, the oil is decomposed, and nitrous gas, disengaged; oxalic acid remaining in the retort. Red and smoking nitric acid, when suddenly mixed with a fixed oil, especially with the addition of a little sulphuric acid, occasions a violent combustion. Chlorine gas, passed through them, thickens them, and renders them tenacious like wax. H.

Action of nitric acid.

1882. The alkalies readily combine with the fixed oils, and form white compounds called *Soap*. Of these the most important is the *soap of soda*, which is thus made: Five parts of barilla are mixed with one of lime and a proper quantity of water. In this way a *ley*, or solution of caustic soda, is obtained, which is boiled in an iron pot with six parts of oil till the soap separates, which is accelerated by the addition of common salt; it is then suffered more perfectly to congeal, and in a few days becomes hard enough to cut into forms.† The best soaps are made with olive oil and soda; in this country animal fat is usually employed for the common soaps, to which resin and some other substances are occasionally added. *Soft Soap* is a compound of potassa with some of the common oils; even fish oil is often used.

Action of alkalies.
Soap.

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* Aikin's *Dictionary*. Art. Soap.

Transparent soap.

Soap furnishes a milky solution with water. It dissolves in alcohol, and the solution, if concentrated, is of a gelatinous consistency. By carefully distilling off the alcohol, a *transparent soap* is obtained.

The acids and the greater number of salts decompose soap, forming in most cases a compound of difficult solubility; hence *hard waters* are unfit for washing, in consequence of containing sulphate of lime; hence also the alcoholic solution of soap is useful as a test for ascertaining the fitness of water for this purpose, which, if it becomes very turbid, cannot in general be used for washing.

When soaps are decomposed by the acids, the oil which they contain is found to have undergone a change, the history of which will be noticed under the head of *animal oils.*

1883. The fixed oils readily combine with oxide of lead, when aided by heat, forming the compound usually termed *plaster;* with the oxides of mercury and bismuth they produce very similar combinations, and are also capable of dissolving white arsenic in large proportion.

1884. The ultimate components of olive oil, as given by Gay-Lussac and Thenard, are

Analysis.

Carbon	77,213
Oxygen	9,427
Hydrogen	13,360
	100.

The analysis may be differently stated as follows:

Carbon	77,213
Oxygen and hydrogen in the proportions to form water	10,712
Excess of hydrogen	12,075
	100.

Olive oil, then probably consists of

10 atoms of carbon	60	76
1 atom of oxygen	8	10
11 atoms of hydrogen	11	14
	79	100

Or supposing each atom of carbon to be associated with 1 of hydrogen, it will contain 10 atoms of olefiant gas, + 1 atom of oxygen and 1 of hydrogen, the two latter probably constituting 1 atom of water. Hence olive oil must contain nine-tenths of its weight of the elements of olefiant gas, in due proportions to form that aëriform compound. H. 2. 229.

Spontaneous combustion.

1885. The fixed oils have a singular property, which has led sometimes to serious accidents. When mixed with lampblack, or with any light kind of charcoal, and even with several vegetable substances, as cotton, wool, or flax, the mixture, after some time, heats spontaneously, and at length bursts into flame. This combustion has sometimes been observed to take place in the waste cotton, employed to wipe the oil from machinery; and has probably occasioned many of the dreadful fires, which have happened in cotton-mills, and for which no adequate cause could be assigned.*

SECTION XI. *Volatile Oils.*

1886. THESE oils are generally obtained by distilling the plants which afford them with water in common stills; the water and oil pass over together, and are collected in the *Italian recipient* shown in fig. 125. in which the water having reached the level *a b*, runs off by the pipe *c.* and the oil being generally lighter than water, floats upon its surface in the space *d.* The whole contents of the recipient are then poured into a funnel, the tube of which is closed with the finger, and when the oil has collected upon the surface, the water is suffered to run from it, and the oil transferred into a bottle. The distilled water being saturated with the oil, should be retained for a repetition of the distillation. The produce of oil is sometimes increased, by adding salt to the water in the still, so as to elevate its boiling point a few degrees. How obtained.

Some of the volatile oils are obtained by expression, such as those of *lemon*, *orange*, and *Bergamot*, which are contained in distinct vesicles in the rind of those fruits.

1887. The volatile oils vary considerably in specific gravity, as will be seen by referring to the *Tables.*

The volatile oils have a penetrating odour and taste, and are generally of a yellowish colour; they are for the most part very soluble in alcohol, and very sparingly soluble in water; these solutions constitute *perfumed essences* and *distilled waters.* The latter are principally employed in pharmacy, and the former as perfumes. Properties.

When pure they pass into vapour at a temperature somewhat above that of 212°, but when distilled with water, they pass over at its boiling point. They are inflammable, and water and carbonic acid are the results of their perfect combustion. As many of these oils bear a very high price, they are not unfrequently adulterated with alcohol and fixed oils. The former addition is rendered evident by the action of water; the latter by the greasy spot which they leave on paper, and which does not evaporate when gently heated. Adulteration.

1888. The volatile oils absorb oxygen, when long exposed to it, and become thick and resinous. They also absorb chlorine. Nitric and sulphuric acids rapidly decompose the volatile oils: Action of oxygen. Chlorine, &c.

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* See Quart. Jour. v. 367.

Exp. a mixture of four parts of nitric, and one of sulphuric acid, poured into a small quantity of oil of turpentine, produces instant inflammation, and muriatic acid is produced, along with a peculiar substance, in some cases not unlike camphor. Iodine produces changes somewhat analogous. Muriatic acid combines with several of them, and forms a crystallizable compound which has been compared to camphor.

The relative quantity of essential oils, furnished from different materials, is liable to much variation; the products of 1 cwt. of the different vegetable substances are given below.*

SECTION XII. *Camphor.*

Soluble in alcohol. 1889. THIS substance in many respects resembles the essential oils; like them it is volatile, inflammable, soluble in alcohol, and sparingly soluble in water.

Specific gravity. In its ordinary state it is white, semi-transparent, and concrete. Its specific gravity ,98. It fuses at about 300°, in close vessels. Action of oils. It dissolves in the fixed and volatile oils. It is scarcely acted upon by the alkalies; some of the acids dissolve, others decompose it.†

If mixed with bole or powdered clay, and repeatedly distilled, it is almost entirely converted into a liquid, having the characters of essential oil.

Extraction. The camphor of commerce is obtained from the *Laurus Camphora*, and comes chiefly from Japan. It is originally separated by distillation, and subsequently purified in Europe in a subliming vessel somewhat of the shape of a turnip, from which the cakes of camphor derive their form.

Action of nitric acid. Camphoric acid. 1890. When camphor is repeatedly distilled with nitric acid it is converted into *camphoric acid.* For this purpose four ounces of camphor, reduced to powder by triturating it with a few drops of spirit of wine, may be introduced into a two-quart tubulated retort, placed in a sand-heat: pour upon it 30 ounces of common nitric acid, and proceed to slow distillation. When two thirds of the acid have passed over, return it into the retort and distil as before, repeating the operation twice more; after which, as the liquor cools, a quantity of crystals of camphoric

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*	Ounces.
Juniper-berries (common)	4 to 5
Ditto. (fine Italian)	7 to 8
Aniseed (common)	32 to 36
Ditto (finest)	36 to 38

		lbs.	oz.		lbs.	oz.
Caraways	from	3	12	to	4	12
Dill-seed	from	2		to	2	6
Cloves	from	13		to	20	
Pimento	from	2		to	3	4
Fennel-seed					2	
Leaves of the *Juniperus Sabina*						14

† Hatchett, *Phil. Trans.* 1805. Chevreul, *Annales de Chimie*, lxxiii.

acid are deposited, which are to be washed and dried. This acid assumes the form of plumose crystals, soluble in about 100 parts of water at 60°, and in rather more than one part of alcohol. Its taste is acid, and somewhat acrid, and it has an aromatic odour. Exposed to heat it sublimes unaltered. It combines with the salifiable bases, constituting a class of salts called *Camphorates*.

1891. The ultimate analysis of camphor has been performed by Dr Ure, who represents its constitution as follows: Analysis.

Carbon	10 atoms	60	78,02
Oxygen	1 atom	8	10,40
Hydrogen	9 atoms	9	11,58
		77	100

1892. When a current of muriatic acid gas is passed through oil of turpentine,* it deposits a concrete substance, which has been called *artificial camphor*, and the weight of which amounts to about one-half of the oil employed. When purified by sublimation with a little quick-lime, it is rendered pure and white. It is lighter than water, sublimes without decomposition, burns like camphor, and in smell resembles a mixture of camphor and turpentine.† By the action of zinc it affords chloride of zinc, and the oil is evolved little altered. Artificial camphor.

1893. Camphor dissolves in sulphuric acid, forming a brown solution, from which it is at first precipitated, unaltered, by water. Sulphurous acid is afterwards evolved, the solution becomes black and thick, and, after some days, affords a brown coagulum on the addition of water, and smells fragrant and peculiar. On distilling the diluted liquor, water and a yellow oil pass over, a little sulphurous acid is then disengaged, and a black matter remains in the retort, which, when digested in alcohol, affords a portion of soluble matter having some of the properties of artificial tannin.‡ Action of sulphuric acid.

SECTION XIII. *Resins.*

1894. RESINS are substances which exude from many trees, either from natural fissures or artificial wounds. Common resin is obtained by distilling the exudation of different species of fir; *oil of turpentine* passes over, and the resin remains behind. It may be taken as a perfect example of resin, and is possessed of the following properties: It is solid, brittle, a little heavier than water, and acquires negative electricity when rubbed. It Properties.

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* Thenard is of opinion that no decomposition of the oil of turpentine takes place; but that the muriatic acid unites to it entire. Ordinary camphor, he supposes from analogy, to be a compound of an essential oil and a vegetable acid.

† Thenard, *Memoires d'Arcueil*, (Tom. ii)

‡ Hatchett, *Phil. Trans.* 1805.

has scarcely any taste or smell; is insoluble in water; readily soluble in alcohol, which takes up about one-third its weight, and becomes milky upon the addition of water. Resin is soluble in the caustic alkalies, the solution is saponaceous, and when mixed with an acid, the resin separates, scarcely altered in its properties. Nitric, muriatic, and acetic acids dissolve it without much change.*

Balsams.

1895. A few of the resins derive odour from containing essential oil; some afford benzoic acid when heated, and these have been termed *balsams; copal, mastich*, and a few others, are very difficultly soluble in alcohol, and contain a substance somewhat analogous to caoutchouc. *Guaiacum* is characterized by the singular changes of colour, which its alcoholic solution suffers when exposed to the action of nitric acid.†

Guaiacum is also rendered blue by the gluten of wheat, but its colour is not changed by starch; the intensity of the blue colour is said to be proportional to the quantity of gluten present in flour.‡

Composition.

1896. There is a remarkable want of agreement between different statements of the composition of the same kind of resin, arising, probably, from actual differences of the substance itself. Dr Ure states the following as the results of his analysis.

Carbon . . . . 75,00 = 8 atoms 48
Oxygen . . . 12,50 = 1 do. 8
Hydrogen . . 12,50 = 8 do. 8
100 64 H. 2. 236.

Lac.

1897. *Lac* is a substance formed by an insect, and deposited on different species of trees chiefly in the East Indies. The various kinds of lac distinguished in commerce, are *stick lac*, which is the substance in its natural state, investing the small twigs of the tree: *seed-lac*, which is the same broken off; and which, when melted, is called *shell-lac*. These substances have been examined by Mr Hatchett. Their component parts are exhibited below.—*Phil. Trans.* 1804.§

Laccic acid.

1898. Dr John has announced the presence of a peculiar acid in stick-lac, which he has called *Laccic Acid.* The lac was

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* The properties of the resins have been very ably investigated by Mr Hatchett, the details of whose researches will be found in his communications to the Royal Society, printed in the *Philosophical Transactions* for 1804, 1805, 1806.

† *Phil. Trans.* 1811.

‡ Taddei, *Giornale de Fisica*, i. 168. *Quarterly Journal*, viii. 376.

	Stick-Lac	Seed-Lac	Shell-Lac.
§ Resin	68	88,5	90,9
Colouring matter	10	2,5	0,5
Wax	6	4,5	4,0
Gluten	5,5	2,0	2,8
Foreign bodies	6,5	—	—
Loss	4,0	2,5	1,8
	100	100	100

digested in water, the solution evaporated, and the residue digested in alcohol: the alcoholic solution was evaporated to dryness, and its residue digested in ether. The evaporation of the etheric solution leaves a yellow matter, which, being again dissolved in alcohol, and the solution mixed with water deposits a little resin, and leaves laccic acid in solution, which, upon the addition of acetate of lead, gives a precipitate of *laccate of lead;* the latter compound, by cautious decomposition by sulphuric acid, affords the laccic acid.

Properties. 1899. Laccic acid is crystallizable, of a yellow colour, a sour taste, and soluble in water, alcohol, and ether. With potassa, soda, and lime, it forms deliquescent soluble salts; with lead and mercury it produces white insoluble compounds; it occasions no precipitate in the nitrates of baryta and silver.*

Gum Resins. 1900. *Gum Resins* are natural combinations of gum and resin, they are consequently only partially soluble in water and in alcohol; they readily dissolve in alkaline solutions when assisted by heat; and the acids act upon them nearly as upon the resins. *Ammoniacum, gamboge, assafœtida,* and *olibanum,* may be taken as examples of gum resins.

Amber. 1901. *Amber* is a substance which, in some of its properties, resembles resin; it is however, very sparingly soluble in alcohol, and difficultly soluble in the alkalies. When submitted to distillation, it furnishes an acid sublimate, which has received the name of *succinic acid.*

Succinic acid. 1902. To prepare this acid, let a glass retort be half filled with powdered amber, and the remainder with fine dry sand. Lute a receiver, and apply a gentle heat. A portion of water first comes over, which is succeeded by a weak acetic acid. The succinic acid then sublimes; but is contaminated by a mixture of oil. It may be purified by solution and crystallization; and it then forms transparent, white, shining crystals, having the form of triangular prisms. They are soluble in 24 times their weight of water, and in boiling alcohol. The solution reddens the blue colour of turnsole, but not that of violets, and has an acid taste, H.—Ten pounds of amber yield about 3 ounces of purified succinic acid.†

Analysis. Berzelius states the composition of succinic acid as follows:

Hydrogen . . .	4,512 =	2 atoms	2
Carbon	47,600 =	4 do.	24
Oxygen . . .	47,888 =	3 do.	24
	100‡		50 H. 2. 238.

Succinates. 1903. Succinic acid combines with the alkalies, &c. and forms *succinates,* the most important of which is the *succinate of*

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* Thomson's *System,* ii. 177.

† Used in Pharmacy under the name of *Oil of Amber* and amounting in weight to about 1-3 the amber used.

‡ Ann. de Chim. 94, 189.

ammonia. This salt decomposes all the solutions of iron; and affords an insoluble precipitate, composed of succinate of iron, of a reddish brown colour. It has been proposed as a means of separating iron in analysis, but is quite inapplicable in the greater number of cases, B.

Uses. 1904. The resins are applied to a variety of useful purposes; and dissolved in alcohol and oils they constitute the different

Varnishes. *varnishes*. The most solid resins yield the most durable varnishes.

SECTION XIV. *Vegetable Alkalies.*

General properties. 1905. THE forces, which produce in living vegetables many acids, appear also to be capable of giving rise to a variety of alkaline substances, several of which have been discovered and identified during the few last years. So far as is yet known, the processes, by which they are obtained, effect nothing more, than their separation from the vegetables in which they exist ready formed. These vegetables are for the most part distinguished by very powerful effects on the animal system, produced, it should appear, by an alkaline ingredient peculiar to each species; and it is probable that the active principles, thus detached, may hereafter become important instruments in the hands of the physician. It is chiefly from their habitudes of chemical combination, that these new substances are classed among alkalies, which they resemble in the power of neutralizing acids, and of affording with them compounds analogous to the salts, which result from the union of acids with the alkaline substances that have been long known. They have all, however, weaker affinities for acids, than belong to alkalies of the latter class; and are destructible, both when separate and in combination, at low degrees of heat. At first they were distinguished by names ending in *ine*, as morphine, strychnine, &c.; but, for the sake of conformity to the nomenclature of other alkalies, their names have since received a different termination.

1906. Besides these alkalies of feeble energy, it has been discovered by Dr Peschier, of Geneva, that potassa, which had been long extracted from the ashes of plants, exists ready formed in their juices, and may be obtained by agitating pure magnesia with the liquor obtained by pressure or decoction of any part of the vegetable, except its fruit. In most plants, the potassa is united with oxalic or tartaric acid, which form insoluble compounds with magnesia; but in borage, the potassa is combined with nitric acid, which magnesia has not the power of detaching from that alkali.* H. 2. 278.

Opium. 1907. *Opium*, and other vegetable products possessed of narcotic power, are composed of several of the vegetable principles that have already been enumerated. Besides these, however, they contain a peculiar one, in which the narcotic virtue resides. Its preparation and chemical qualities have been investigated by Derosne, whose memoir is published in the 45th volume of the Annales de Chimie.

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* Ann of Philos. xii. 336.

To obtain the narcotic principle from opium by the process of Derosne, let water be digested upon it, and the strained solution be evaporated to the consistence of sirup. A gritty precipitate will begin to appear, which is considerably increased by diluting the liquid with water. This consists of three distinct substances, resin, oxygenized extract, and the narcotic principle. Boiling alcohol dissolves the resin and narcotic principle only; and the latter falls down in crystals, as the solution cools, still, however, coloured with resin. The crystals may be purified by repeated solutions and crystallizations. H.

Morphia.

1908. *Mòrphia* may be obtained from powdered opium by triturating it into a paste with dilute acetic acid: pour caustic ammonia into the filtered solution, and evaporate; during the evaporation a brownish substance separates, which, by digestion in a small quantity of cold alcohol, becomes nearly colourless, and is pure morphia.*

Properties.

1909. Morphia is sparingly soluble in water, but readily soluble in alcohol and in ether, from which it may be obtained in quadrangular and octoëdral crystals. It is highly poisonous and narcotic, even when administered in very small doses; it is fusible and combustible. It appears in some respects to possess the properties of an alkali; it reddens turmeric, and forms crystallizable compounds with the acids.

Effects.

1910. Its effects on the human body are those of a most violent poison. Three half grains, taken in succession with intervals of half an hour by the same person, produced violent vomitings and alarming faintings. H.†

1911. In opium morphia is said to be combined with a peculiar acid, which has been called the *meconic acid*, and this combination is decomposed by the action of ammonia in the preparation of morphia.

Meconic acid.

The following process is said to afford pure meconic acid: Boil infusion of opium with magnesia, and digest the precipitate in alcohol; *meconiate of magnesia* remains: dissolve this in dilute sulphuric acid, and add muriate of baryta, a precipitate falls, composed of sulphate and *meconiate of baryta;* digest this in dilute sulphuric acid, which decomposes the meconiate: filter and evaporate, till brown crystals of impure meconic acid are deposited; dry these crystals, and then heat them carefully in a retòrt, to sublime the meconic acid. White crystals are thus obtained, which fuse at 250°, and sublime without decomposition; they are sour, and very soluble in water and alcohol.

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* See another process by Dr Thomson in *Ann. Philos.* xv. 470.

† Tinctures of opium, it is observed by Sertuerner, should be prepared with pure alcohol, and kept in a place which is not very cold; for a low temperature precipitates morphia. The addition of a little acetic acid prevents this inconvenience. H.

Meconiate of Morphia. 1912. *Meconiate of Morphia* may be obtained by the following process. Reduce good opium to powder, put it upon a paper filter, add distilled water to it, and slightly agitate it; in this way wash it till the water passes through colourless; then pass a little diluted alcohol through it; dry the insoluble portion in a dark place; digest it in strong alcohol for a few minutes, applying heat; separate the solution, which, by cooling and subsequent evaporation, will yield the crystallized meconiate of a pale straw colour.*

Strychnia. 1913 MM. Pelletier and Caventou, in analyzing the *bean of St. Ignatius* (*Strychnos Ignatia*), and the *vomica nut* (*Strychnos nux vomica*), discovered in them a peculiar principle, which they have termed *Strychnine*, and which, like morphia, possesses alkaline properties. The following is their process for obtaining it: Digest the raspings of the bean in sulpuric ether, which separates a green oily fluid; pour this off, and treat the residuum with alcohol; filter the latter solution when cold, and evaporate; it leaves a brown bitter substance, soluble in water and alcohol; to its strong aqueous solution add a solution of potassa, which causes a precipitate, which, when washed with a little cold water, is white, crystalline and very bitter. If not quite pure, it may be rendered so by solution in acetic acid, and precipitation by potassa.

1914. Strychnine, or *Strychnia*, is nearly insoluble in water; it dissolves in alcohol, and the solutions are intensely bitter and poisonous. It reproduces the blue of vegetable colours reddened by acids. It crystallizes in small quadrangular prisms; it has no smell; and is neither fusible nor volatile, but is decomposed at about 600° into products consisting of oxygen, hydrogen, and carbon.

Salts of 1915. The *Salts of Strychnia* are decomposed by potassa, soda, ammonia, baryta, strontia, and magnesia, the base being thrown down; most of the other metallic salts are decomposed by strychnia, and with some it forms, triple salts.

Sulphate. 1916. *Sulphate of Strychnia* forms cubic crystals, soluble in about 10 parts of water at 60°; its taste is bitter, and it is decomposed by the alkalies. It consists of sulphuric acid 9,5 strychnia 90,5.

Nitrate. 1917. *Nitrate of Strychnia* is formed by digesting excess of strychnia in very dilute nitric acid; it yields stellated crystals, which acquire a red colour by the action of sulphuric acid. Nitric acid poured upon strychnia or its salts produces a deep red colour.

1918. The discoverers of strychnia assert that it exists in the above-mentioned seeds, combined with a peculiar acid, somewhat resembling the malic, but susceptible of crystallization;

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* Dr Meneci, *Quart. Jour.* xl.

they have called it *Igasuric Acid*, and the poisonous principle existing in the seeds, appears to be an *igasurate of strychnia*.

1919. *Brucia*. This term has been applied to a peculiar alkaline substance, obtained from Angustura bark, by the above-named chemists. Its properties, as far as they have been investigated, are described in the *Annales de Chimie* (xii. p. 113.) and in the *Quarterly Journal of Science and the Arts* (ix. 189.) Brucia.

1920. *Delphia* is an alkaline principle, discovered by MM. Lassaigne and Feneulle in the seeds of stavesacre (*Delphinium Staphysagria*). They obtained it by the following process: The seeds, deprived of their husks, were boiled in distilled water, the decoction filtered, boiled with a portion of pure magnesia, and re-filtered; the residue upon the filter was then boiled with highly rectified alcohol, by which the alkali was separated and obtained by evaporation in the form of a white pulverulent substance. Delphia.

Delphia, when pure, appears crystalline in its moist state; its taste is bitter and acrid; when heated, it melts, and on cooling becomes brittle like resin; it is sparingly soluble in water, but readily soluble in alcohol and ether; it renders the blue of violets green, and forms very soluble salts with the acids, from which the alkalies precipitate delphia in a white gelatinous state.* Properties.

SECTION XV. *Bitumens, coal, &c.*

1921. THOUGH bitumens, on account of their origin, are, with more propriety, classed among mineral substances; yet, in chemical properties, they are more closely allied to the products of the vegetable kingdom. Like vegetable substances in general, they burn in the open air, and with a degree of brightness that surpasses even that of resins. By distillation *per se*, they yield a weak acetic acid, an empyreumatic oil, some ammonia, and a considerable quantity of carburetted hydrogen gas, with occasionally a small proportion of carbonic acid and sulphuretted hydrogen. They are neither soluble in water nor in alcohol, and in the latter respect they differ from resin. There can be little doubt that they have been formed originally by the decomposition of vegetables. Bitumens.

1922. The bitumens have been divided into liquid and solid. Formerly it was supposed that the liquid bitumens had been derived, by a sort of natural distillation, from the solid; but Mr Hatchett has rendered it more probable, that the solid bitumens result from the consolidation of the fluid ones. How divided.

The bituminous substances are Naptha, Petroleum, Mineral Tar, Mineral Pitch, Asphaltum, Jet, Pit-Coal, Bituminous wood, Turf, and Peat. To these, some writers have added Amber and the Honey-Stone.

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* Annales de Chimie et Phys. xli. 358.

Naptha. *a. Naptha* is a pungent, odoriferous, oily liquid, either colourless or of a pale brown tint, found upon the borders of the Caspian Sea, and in certain springs in Italy. It is considerably lighter than water, volatile, and highly inflammable. When pure it appears to contain no oxygen, and hence is employed for the preservation of potassium, and the other highly oxidable metals. It consists, according to Saussure, of

Analysis.

Carbon	87,21
Hydrogen	12,79
	100,

This would indicate

6 atoms of carbon	36	88
5 " " hydrogen	5	12
	41	100 H.

Petroleum. *b. Petroleum* has most of the properties of naptha, but is less fluid, and darker coloured. In the countries where it abounds, it is employed for burning in lamps.

c. Mineral Tar appears to be petroleum further inspissated. It is more viscid, and of a deeper colour.

d. Maltha, or *Mineral Pitch*, is a soft inflammable substance, heavier than water, and may be considered as derived from the exsiccation of mineral tar.

Asphaltum. *e. Asphaltum* is found abundantly on the shores of the Dead Sea, in Albania, and in the island of Trinidad. Its colour is brown or black; it is heavier than water, and readily soluble in naptha.

f. Elastic Bitumen, or *Mineral Caoutchouc*, is found in the vicinity of Castleton, Eng. and at Southbury in the state of Connecticut.* It is fusible and inflammable.

g. Mineral Adipocere is a fatty matter found in the argillaceous iron ore of Merthyr: it is fusible at about 160°, and inodorous when cold, but of a slight bituminous odour when heated, or after fusion.

The above substances are insoluble in water, and difficultly soluble in alcohol, with the exception of naptha and petroleum, which are soluble in highly rectified alcohol.

Retinasphaltum. *h. Retinasphaltum* is a substance which accompanies the Bovey Coal of Devonshire. It was first analyzed by Mr. Hatchett, who found it to consist of

55	Resin.
41	Asphaltum.
4	Earthy matter and loss.

Pit Coal. *i. Pit coal.* There are three chemical varieties of this important substance. The first, or *brown coal*, retains some remains of the vegetables from which it has originated. When heated it exhales a bituminous odour, and burns with a clear flame. It is generally of a tough consistency and yields according to Mr. Hatchett, a portion of unaltered vegetable extract, and resin.

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* Amer. Jour. vi 370.

The second variety, or *black coal,* is the ordinary fuel of Great Britain. It exhibits no traces of vegetable origin, and consists principally of bitumen and charcoal, in variable proportions. When exposed to heat, it swells, softens, and burns with a bright flame, leaving a small quantity of ashes. Many varieties, however, abound in earthy matter, and these produce copious cinders, and burn with a less intense heat.

The products of the destructive distillation of this kind of coal have been already described (693). The residue is a hard sonorous charcoal, termed *coke,* and containing the earthy ingredients of the coal.

The third variety, *glance coal* or *anthracite,* consists almost entirely of charcoal, and earthy matter.

It usually burns with little flame* and when submitted to distillation yields no tar, and a sort of carburetted hydrogen gas.

Peat. *k.* ***Peat*** and ***Turf*** consist principally of the remains of vegetables, having undergone comparatively little change. They often contain bituminous wood, and branches and trunks of trees.

Mellite. *l.* ***Mellite,*** or ***Honeystone,*** is a rare substance, found in the brown coal of Thuringia and in Switzerland. It is of a honey yellow colour, crystallized in octoëdra, and when analyzed by Klaproth, was found to consist of alumina combined with a peculiar body which has been called the *mellitic acid.*†

SECTION XVI. *Vegetable Acids.*

1923. THE following are the principal acids, which are found ready formed in vegetable products:

1. Pectic acid.
2. Tartaric acid.
3. Oxalic acid.
4. Citric acid.
5. Malic acid.
6. Gallic acid.
7. Benzoic acid.

i. PECTIC ACID.

Pectic acid, 1924. This new acid has been discovered by M. H. Braconnot and receives its name from πηκτις, *coagulum,* in consequence of its resembling a jelly or gum. It is found in all vegetables; is sensibly acid, reddens turnsole paper, and is scarcely soluble in cold water, but more so in hot water. It is coagulated into a transparent and colourless jelly by alcohol, by all the metallic solutions, by lime-water, water of baryta, the acids, muriate and sulphate of soda, nitre, &c.

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* The anthracite of this country burns with considerable flame, see *Amer. Jour.* x. 338.

† Klaporth's *Essays,* ii. 89. Vauquelin. *Annales de Chimie,* xxxvi. 203.

How obtained. 1925. It is easily obtained from all parts of plants. If roots containing starch be operated upon, such as those of cellery and carrot, they are to be reduced to pulp by rasping, the juice expressed, the residue boiled in water, slightly acidified with muriatic acid, then washed, and afterwards heated with a very dilute solution of potassa or soda. A thick mucilaginous liquid results, slightly alkaline, from which muriatic acid separates the pectic acid in the form of an abundant jelly, which should then be well washed.

Union with potassa. 1926. It forms a very soluble salt with potassa, which may be obtained in the state of a transparent jelly, by adding weak alcohol, which removes the excess of alkali and colouring matter if there be any present. This jelly washed on a cloth with alcoholized water, pressed and dried, is a neutral compound, which swells and dissolves in water, and leaves upon evaporation a transparent mass, resembling gum arabic. Its taste is insipid. Placed upon a plate of red hot iron it swells excessively, leaving a deep brown residue soluble in water and having the character of ulmin united to potassa. Exposed to the flame of a taper, it burns, producing delicate filaments which project from the mass like vermicelli. These filaments fuse into globules of sub-carbonate of potassa.

Properties.

This salt has the remarkable effect of communicating to large masses of sugar and water the property of gelatinizing. M. Braconnot in this way prepared aromatised jellies, perfectly transparent and colourless and very agreeable to the taste and eye.

Unites with ammonia. 1927. This acid forms with ammonia a soluble compound having similar properties to the foregoing.*

ii. Tartaric Acid.

1928. This acid exists in several vegetable substances; it is one of the sour principles of many fruits, and is said to be abundant in the potato-apple. Tartaric acid is generally obtained from the *bi-tartrate of potassa*, (*purified cream of tartar*.) Mix 100 parts of this salt in fine powder with 30 of powdered chalk, and gradually throw the mixture into 10 times its weight of boiling water: when the liquor has cooled, pour the whole upon a linen strainer, and wash the white powder which remains with cold water: this is a *tartrate of lime*; diffuse it through a sufficient quantity of water, add sulphuric acid equal in weight to the chalk employed, and occasionally stir the mixture during 24 hours; then filter, and carefully evaporate the liquor to about one fourth its original bulk; filter again, and evaporate with much care nearly to dryness; re-dis-

Mode of obtaining.

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* Ann. de Chim. xxviii, 173, and Boston Jour. iii. 132.

solve the dry mass in about 6 times its weight of water, render it clear by filtration, evaporate slowly to the consistency of sirup, and set aside to crystallize. By two or three successive solutions and crystallizations, tartaric acid will be obtained in colourless crystals, soluble in 6 parts of water at 60°. Their primary form is an oblique rhombic prism.*

1929. The crystals melt at a heat a little exceeding 212° into a fluid which boils at 250° and leaves a semi-transparent mass on cooling, slightly attractive of moisture from the air, though the original crystals were not deliquescent. They were found by Berzelius to consist of

Properties:

Real acid	88,75	100
Water	11,25	12,7
	100,	H. 2. 211.

The aqueous solution of tartaric, in common with the other vegetable acids, soon becomes mouldy, and suffers decomposition.

1930. When tartaric acid is submitted to destructive distillation, it affords a brown acid liquor which has been termed *pyrotartarous acid.*

Pyrotartarous acid.

1931. According to Berzelius, the *tartrate of lead*, which is an insoluble salt, and easily formed by adding tartaric acid to a solution of nitrate of lead, consists of

Tartaric acid	100
Oxide of lead	167

And regarding this salt as composed of 1 proportional of acid and 1 of oxide, we obtain the number 67,0 as the representative of tartaric acid, for

167 : 100 : : 112 : 67,0

1932. Tartaric acid combines with the metallic oxides, and produces a class of salts called *tartrates*, the composition of which will be obvious from the preceding datum.

Tartrates.

1933. *Tartrate of ammonia* forms very soluble prismatic crystals, of a cooling taste. The addition of tartaric acid to its aqueous solution produces a precipitate of a difficultly soluble *bi-tartrate* of ammonia.

Of ammonia.

1934. *Tartrate of Potassa*, (formerly *soluble tartar*) is formed by saturating the excess of acid in *tartar*, by potassa. According to Mr. Richard Phillips (*Remarks on the Pharmacopœia*,) 100 parts of tartar require 43,5 of carbonate of potassa. The resulting salt is soluble in less than twice its weight of water; it crystallizes in four-sided prisms, and consists of

Of potassa.

1 proportional acid	= 67.
1 .... potassa	= 48.
Tartrate of potassa	= 115.

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* Brooke in *Ann. Philos.* vi. N. S.

This salt is used in pharmacy as an aperient; it is the *potassæ tartras* of the *Pharmacopœia.* Its taste is saline, and somewhat bitter.

Bitartrate or crude tartar.

1935. *Bi-tartrate*, or *Supertartrate of potassa. Tartar.* This substance exists in considerable abundance in the juice of the grape, and is deposited in wine casks, in the form of a crystallized incrustation; called, *argol* or *crude tartar.* It is purified by solution and crystallization, which renders it perfectly white: when in fine powder it is termed *cream of tartar.*

Tartaric acid test for potassa.

It may also be formed by adding excess of tartaric acid to a solution of potassa. The mixture presently deposits crystalline grains, and furnishes a striking example of the diminution of solubility by increase of acid in the salt. Upon this circumstance the use of tartaric acid as a test for potassa depends, for soda forms an easily soluble supertartrate and consequently affords no precipitate. (898)

Bi-tartrate of potassa is composed of

2 proportionals of acid	=	134
1 proportional of potassa	=	48
Bi-tartrate of potassa	=	182

contains water.

1936. In the bi-tartrate, is also found a quantity of water which appears essential to the constitution of the salt; for it cannot be separated by heat, without decomposing the acid. Its proportion is nearly that of an atom.* H.

Bi-tartrate of potassa, it is observed by Gay-Lussac,† acts, in many cases, like a simple acid, and even dissolves oxdies that are insoluble in the mineral acids and in the tartaric acid. He proposes its use, therefore, in mineral analysis. H.

Effect of heat.

1937. When exposed to heat, tartar fuses, blackens, and is decomposed: and carbonate of potassa is the remaining result. Provided the tartar be free from lime, which however is seldom the case, this furnishes a good process for obtaining pure carbonate of potassa. The aqueous solution of tartar becomes mouldy when exposed to air, and the tartaric acid being entirely decomposed leaves a weak solution of carbonate of potassa.

The component parts of tartar render it an excellent flux in the reduction of metallic ores upon a small scale, its alkali promoting their fusion, and the carbonaceous matter tending to reduce the oxides.

Tartrate of soda.

1938. *Tartrate of Soda* forms acicular crystals soluble in their own weight of water. Tartaric acid, added to their solu-

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* The destructive distillation of 1000 parts of bi-tartrate of potassa, gave the following results, exclusive of gaseous products, of acid, and charcoal.

Pure dry sub-carbonate of potassa	350
Tartrate of lime	6
Silica	1,2
Alumina	0,25
Iron and manganese	0,75

Fourcroy and Vauquelin, *Ann. de Chim.* 44. [illegible]

† Ann. de Chim. et Phys. iii. 281.

tion, forms a *supertartrate of soda*, much more soluble than the corresponding salt of potassa.

— of potassa and soda.

1939. *Tartrate of Potassa and Soda* is prepared by saturating the excess of acid in tartar, with carbonate of soda; it is the *tartras potassæ et sodæ* of the *Pharmacopœia;* it forms irregular prismatic crystals. It has long been used in pharmacy under the name of *Rochelle Salt* and *Sel de Seignette.* According to Vauquelin's analysis[*] this salt consists of 54 tartrate of potassa + 46 tartrate of soda *per cent.:* these numbers agree with

2 proportions of acid . . . = 134
1 ———————— potassa . = 48
1 ———————— soda. . . = 32
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214

— of iron and potassa.

1940. *Tartrate of Iron and Potassa.* This is the *Ferrum tartarisatum* of the London *Pharmacopœia*, but it is most conveniently employed as a medicine in solution, which may be formed by digesting 1 part of soft iron filings with 4 of tartar; this mixture should be made into a thin paste with water, and digested for some weeks, till the acid is neutralized, fresh portions of water being occasionally added to prevent exsiccation. The solution of this compound which contains the iron in the state of peroxide, is possessed of some curious properties, first pointed out by Mr R. Phillips.[†]

1941. *Tartrate of Potassa and Copper* is formed by boiling oxide of copper and tartar in water: the solution yields blue crystals on evaporation; or if boiled to dryness, furnishes one of the pigments called *Brunswick green.*

— of antimony and potassa.

1942. *Tartrate of Antimony and Potassa Emetic Tartar.* This compound may be obtained by boiling protoxide of antimony, obtained by any of the processes formerly described (1272) with pure supertartrate of potassa. It is the *antimo-*

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[*] Fourcroy's *Connaissances*, vii. 240.

[†] Experimental Examination of the London Pharmacopœia, 98.[‡]

[‡] *Tartrate of Lime* is nearly insoluble in cold water, but soluble in 600 parts of boiling water; it is produced by adding chalk to tartar, as in the process for obtaining tartaric acid, where it is decomposed by sulphuric acid. *Tartrate of Potassa and Lime* may be formed by adding lime-water to solution of supertartrate of potassa, till it begins to become turbid: in a few days acicular crystals of the above triple salt are deposited, which effloresce when exposed to air.—*Tartrate of Strontia* is thrown down on mixing the solutions of tartrate of potassa and nitrate of strontia. It dissolves in rather more than 300 parts of boiling water, and forms small crystals as the solution cools.—*Tartrate of Magnesia* is precipitated from the sulphate by tartaric acid: it is soluble in excess of tartaric acid, and forms a crystallizable salt.—*Tartrate of Manganese*, formed by dissolving protoxide of manganese in tartaric acid, is a soluble salt, and therefore not produced by adding tartaric acid or a neutral tartrate to protomuriate or protosulphate of manganese.—*Tartrate of Iron.*—Both the tartrates of iron are easily soluble, and no precipitate is formed by tartaric acid, or by tartrate of potassa, in solutions of iron.—*Tartrate of Zinc* is formed by adding tartrate of potassa to sulphate of zinc, and appears to be a very difficultly soluble compound.—*Tartrate of Tin.*—Tartrate of potassa occasions a white precipitate in the protomuriate and permuriate of tin.—*Tartrate of Potassa and Tin* is formed by boiling the oxide in solution of tartar; it is very soluble, and the addition of alkalies and their carbonates occasion no precipitates. Thenard, *Annales de Chim.* xxxviii.—*Tartrate of Lead* is thrown down in the form of an insoluble white powder on adding tartaric acid to solution of nitrate of lead.—*Tartrate of Potassa and Lead* is formed, according to Thenard, by boiling a mixture of tartar and oxide of lead in water. *Annales de Chim.* xxxvii.

nium tartarizatum of the *London and U. S. Pharmacopœiæ.*

Preparation of emetic tartar.

Emetic tartar may be prepared by boiling a solution of 100 parts of tartar with 100 parts of finely levigated glass of antimony, or of the protoxide described above (1272); the ebullition should be continued for half an hour, and the filtered liquor evaporated to about half its bulk, and set aside to crystallize: octoëdral and tetraëdral crystals of the emetic salt are thus obtained; and there is generally formed along with them a portion of tartrate of lime and potassa, which is deposited in small tufts of a radiated texture, and which may easily be separated when the mass is dried.

Mr Phillips, in his *Experimental Examination of the London Pharmacopœia*, has stated several facts respecting the formation of this salt, which will be found useful to the manufacturer.*

Properties.

Emetic tartar is a white salt, slightly efflorescent, soluble in about 14 parts of cold and 2 parts of boiling water. It is decomposed by the alkalies, and when heated with ammonia, a portion of protoxide of antimony is thrown down, and a very soluble compound remains in the liquor. Sulphuretted hydrogen and hydrosulphuret of ammonia produce orange-coloured precipitates in its solution. It is decomposed by bitter and astringent vegetable infusions, but they do not render it inactive as a medicine. In a late analysis Mr Phillips has shown that emetic tartar consists of

Analysis.

Bi-tartrate of potassa (anhydrous)	49,25
Protoxide of antimony	43,35
Water	7,40
	100.

and he considers it as composed of 1 atom of bi-tartrate of potassa, 3 atoms of protoxide of antimony, and 3 atoms of water.†

iii. OXALIC ACID.

1943. This acid is found in some fruits, and in considerable quantity in the juice of the *Oxalis Acetosella*, or *wood-sorrel*, and in the varieties of *rhubarb*.‡ It is most readily procured by the action of nitric acid upon sugar, and has hence been termed *acid of sugar*.

How obtained.

It may be obtained by introducing into a retort 4 ounces of nitric acid diluted with 2 of water and 1 ounce of white sugar; nitric oxide gas is copiously evolved, and when the sugar has dissolved, about one-third of the acid may be distilled over: the contents of the retort are then emptied into a shallow vessel, and in the course of two or three days an abundant crop of white crystals is deposited, and, upon further evaporation of the mother-liquor, a second portion is obtained. The whole crystalline produce is to be re-dissolved in water, and again crystallized, by which the pure acid is obtained. In this way sugar yields rather more than half its weight of oxalic acid.

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* See Bigelow's *Sequel*, 75.

† Mag. lxv. 379.—For other tartrates, see Henry's *Chemistry*, ii. 215.

‡ M. Braconnot has lately found it in great quantity in combination with lime, in most species of lichens. See his memoir in the *Ann. de Chim.* xxviii. 318 and *Quart. Jour.* xix. 353.

M. Braconnot obtained oxalic acid by the following process from lichens. The lichen reduced to powder was boiled with carbonate of soda, the filtered liquor, was saturated with nitric acid, and acetate of lead was added, the precipitate was decomposed by sulphuric acid; and, a nearly colourless solution was obtained from which crystals of oxalic acid separated. Another portion was afterwards separated from the residue left by the carbonate of soda.

Another process.

1944. The same chemist has employed the following process; 100 parts of the pulverized lichen were boiled with 33 parts of sulphuric acid and a sufficient quantity of water, for half an hour, filtered to separate the sulphate of lime, and the liquid was carefully evaporated avoiding the reaction of the excess of sulphuric acid on the oxalic acid. When cold it became crystalline, and by pressure in bibulous paper 17 parts of yellowish white oxalic acid were obtained, some still remaining dissolved.*

Characters.

1945. Oxalic acid has the form of an oblique rhombic prism. The crystals are transparent, and of a very acid taste: they dissolve in two parts of water at 60°, and in their own weight at 212°. They are soluble, also, in boiling alcohol, and sparingly in ether. The crystals effloresce in the air; and a red heat decomposes them. During distillation, a considerable quantity of inflammable gas is obtained, and a portion of the acid is sublimed, unaltered, into the neck of the retort.

Decomposed by gold.

1946. Oxalic acid is decomposed both by the oxides and chloride of gold, and in the former case with a disengagement of carbonic acid.†

Composition

1947. The crystals of oxalic acid are, according to Dr Thomson‡ composed of 1 atom acid and 4 atoms of water.—From the results of its analysis, considered in connection with the proportions in which it combines with bases, it appears extremely probable that oxalic acid consists of

	Atoms.		
Carbon	2	12	33,34
Oxygen	3	24	66,66
		36	100.

H. 2. 189.

How distinguished from Epsom salts.

1948. This acid is a most virulent poison and from the resemblance which the crystals bear to those of Epsom salt, many fatal mistakes have arisen. The acid taste is in itself a sufficient mark of distinction; or without tasting it, if a few drops of water be placed on a slip of the dark blue paper which is commonly wrapped round sugar loaves, and a small quantity of the suspected crystal be added, if it be oxalic acid it will change the colour of the paper to a reddish brown. The solution also of a small quantity of this acid in a tea-spoonful of water, will effervesce with a little scraped chalk or whiting. H.—When the acid has been swallowed copious draughts of lime water, or magnesia and water should be administered, and vomiting excited as speedily as possible.

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* Ann. de Chim. xxviii. 318.

† Ann. de Chim. et Phys. xv. 125.

‡ First Prin. ii. 103.

Test of lime.

1949. Oxalic acid is a good test for detecting lime, which it separates from all other acids, unless they are present in excess.

Oxalate of ammonia.

1950. *Oxalate of Ammonia* is a very useful test of the presence of lime. It crystallizes in long prisms, of which 45 parts require 1000 of water. Added to any soluble compound of lime this salt produces an insoluble *oxalate of lime.*

— of potassa.

1951. *Oxalate of Potassa* forms flat oblique four-sided prisms, terminated by dihedral summits, the lateral edges of the prism being usually bevelled. Its taste is cooling and bitter. At 60° F. it requires about twice its weight of water for solution. There is also a salt, formed of the same base and acid, but with a considerable excess of acid, called *super-oxalate* or *bin-oxalate of potassa.* It forms small white parallelopipeds or rhomboids approaching to cubes. It has a pungent acid taste mixed with some bitterness. It requires for solution ten times its weight of water at 60°, and a still larger proportion of boiling water. It may either be formed artificially, or obtained from the juice of the *oxalis acetosella*, or of the *rumex acetosa.* When procured in the latter mode, it is sold under the name of *salt of sorrel*, or *essential salt of lemons.* The acid, which it contains is double that in the oxalate; or if we suppose 100 parts of potassa, and denote the quantity necessary to convert it into oxalate by x, then $2x$ will convert it into bin-oxalate.

Salt of Lemons.

According to Berzelius, 100 parts of potassa are united, in the oxalate, with 76,58 parts of real oxalic acid, and in the binoxalate, of course, with 153,16. Exclusively of water, which in the crystals of the oxalate, amounts to 17,31 per cent. they are composed as follows:

	Acid.	Base.
Oxalate of potassa . .	43,37	56,63
Binoxalate of ditto . .	60,47	39,53

Quadroxalate of potassa.

1952. *Quadroxalate of Potassa* may be composed by several methods.* It was formed by Dr Wollaston, by digesting the bin-oxalate in nitric or muriatic acid. The alkali is divided into two parts, one of which unites with the mineral acid, and the other half remains in combination with the oxalic acid. It forms beautiful crystals, which may be obtained pure by solution and a second crystallization.

If three parts by weight of the quadroxalate be decomposed by burning, and the alkali, which is thus disengaged, be mixed with a solution of one part of the crystallized salt, the latter is exactly neutralized. Hence the quadroxalate contains four times the acid that exists in the oxalate. The analysis of this class of salts, from which Dr Wollaston (in the Phil. Trans. for 1808) drew a striking exemplification of the law of simple multiples discovered by Mr Dalton, may be recapitulated as follows:

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* See Berard, 73 *Ann. de Chim.* 271.

Composition.

	Atom of base.		Atoms of acid.		Base.		Acid.		Equivalent Number.
The oxalate consists of	1	+	1	. . .	48	+	36	=	84
The binoxalate	1	+	2	. . .	48	+	72	=	120
The quadroxalate . . .	1	+	4	. . .	48	+	144	=	192

Estimating, therefore, from the weights of their atoms, 100 of potassa should be united, in the oxalate, with 75 of acid; in the binoxalate, with 150; and in the quadroxalate, with 300. H. 2. 189.

Oxalate of lime.

1953. *Oxalate of Lime.* This compound is formed by adding oxalic acid or oxalate of ammonia to any solution of lime. It is insoluble in water, and in excess of oxalic acid, but dissolves in muriatic and nitric acids: hence in testing acid solutions for lime by oxalic acid, or oxalate of ammonia, the excess of acid should be previously neutralized. This oxalate, dried in the temperature of 95° Dr Thomson finds is composed of 1 atom oxalic acid, 1 lime, and 2 atoms of water.—The anhydrous salt consists of

Composition.

Lime	1 atom . . .	28	43,75
Oxalic acid	1	36	56,25
		64	100* H.

1954. The *Oxalates of Strontia, Baryta,* and *Magnesia,* are very nearly insoluble, and with most other metallic oxalates may be formed by double decomposition. They consist respectively of one proportional of each of their components.

Of Strontia, &c.

1955. When black oxide of manganese and superoxalate of potassa are triturated together and moistened, carbonic acid is evolved; and on adding more water, and filtering, a red solution, containing oxalic acid, potassa, and deutoxide of manganese is obtained, which after a time becomes colourless, and a triple salt is formed, containing the protoxide of manganese.

Of iron.

1956. *Oxalate of Iron.* The *protoxalate* crystallizes in green prisms, and may be formed either by digesting the metal, or dissolving the protoxide in the acid. The *peroxalate* is thrown down from the permuriate or persulphate of iron, in the form of a difficultly soluble yellow powder, which is taken up again by excess of oxalic acid: hence the use of this acid in removing iron-moulds which it does without injuring the texture of linen.

Of copper and ammonia.

1957. *Oxalate of Copper and Ammonia.* This and several other triple oxalates of copper have been described by Vogel.† By digesting peroxalate of copper in a solution of oxalate of ammonia and filtering, rhomboidal crystals were obtained on evaporation, which detonate when suddenly heated: when slowly heated they merely lose water and ammonia. From the analysis of this salt it evidently consists of 2 proportionals of oxalate of ammonia, 1 peroxalate of copper, and 6 water.

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* *Oxalate of Soda* is sparingly soluble in water, and separates from its solution in small crystalline grains.

† Schweigger's *Journal*, vii.

By digesting oxalate of copper in caustic ammonia, and pouring the solution thus obtained into a shallow basin, it deposits flat six-sided prisms of a blue colour, which effloresce on exposure to air. The undissolved portion of the oxalate also combines with ammonia, and produces another distinct compound.*

iv. Citric Acid.

1958. Citric acid is obtained by the following process from lemon or lime juice:

How prepared. Boil the expressed juice for a few minutes, and when cold, strain it through fine linen; then add powdered chalk as long as it produces effervescence, heat the mixture, and strain it as before: a quantity of citrate of lime remains upon the strainer, which, having been washed with cold water, is to be put into a mixture of sulphuric acid with 20 parts of water: the proportion of acid may be about equal to that of the chalk employed. In the course of 24 hours the citrate of lime will have suffered decomposition, and sulphate of lime is formed, which is separated by filtration. The filtered liquor, by careful evaporation, as directed for tartaric acid, furnishes crystallized citric acid.

The preparation of this acid is carried on by a few manufacturers upon an extensive scale; in different states of purity it is employed by the calico-printers, and used for domestic consumption. Many circumstances which have not here been alluded to, are requisite to ensure complete success in the operation; these have been fully described by Mr Parkes, in the third volume of his *Chemical Essays.* The proportion of citric acid afforded by a gallon of good lemon-juice, is about 8 ounces.

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* *Oxalate of Zinc* is formed by adding oxalic acid to a soluble salt of zinc: it is a white powder, nearly insoluble.—*Oxalate of Tin* is formed, according to Bergman, by digesting the metal in the acid: the solution, slowly evaporated, gives prismatic crystals.—*Oxalate of Copper.* Oxalic acid oxidizes and dissolves copper. When oxalic acid is added to persulphate or pernitrate of copper, a difficultly soluble *peroxalate of copper* is thrown down.—*Oxalate of Copper and Potassa* is obtained by digesting percarbonate of copper in solution of binoxalate of potassa. Acicular and rhomboidal crystals are formed, which Vogel considers as two distinct salts.—*Oxalate of Lead* is thrown down in crystalline grains on adding oxalic acid to nitrate of lead.—*Oxalate of Bismuth* is deposited in crystalline grains, when solution of oxalic acid is dropped into nitrate of bismuth.—*Oxalate of Cobalt* is an insoluble red powder, precipitated by oxalic acid from solutions of cobalt.—*Oxalate of Nickel* is thrown down from the nitrate in the form of an insoluble green powder.—*Oxalate of Mercury* is precipitated from the nitrate by oxalic acid. It is scarcely soluble, and detonates, when heated.—*Oxalate of Silver* is an insoluble white powder, which blackens by exposure to light. It is precipitated on adding oxalic acid to nitrate of silver, and is soluble in nitric acid.—*Oxalate of Alumina* is easily formed by dissolving the newly precipitated earth in oxalic acid: it does not crystallize, but affords on evaporation a gelatinous mass, which deliquesces on exposure.

For other oxalates see Henry's Chemistry, ii. 192.

Characters.

1959. Citric acid forms crystals of a very sour taste, soluble in their own weight of water at 60°, and containing, according to Berzelius, 79 (1 atom) real acid + 21 (2 atoms) water, a portion of which it loses by exposure to heat. The analysis of this, as well as of the other vegetable acids given by Berzelius, differs considerably from that of Gay-Lussac and Thenard, in consequence, as it would appear, of the latter chemist having neglected the exclusion of water of crystallization. Berzelius gives its constituents as follow:

Composition.

Oxygen	54,831
Hydrogen	3,800
Carbon	41,369
	100,000

1960. From the analysis of citrate of lead, the representative number of citric acid appears to be a number which closely corresponds with Berzelius's estimate of its constitution, which is

4	Proportionals of	oxygen	8 × 4 =	32	55,17
2	———	hydrogen	1 × 2 =	2	3,45
4	———	carbon	6 × 4 =	24	41,38
				58	100.

The number 58, therefore, may be adopted.

Citrates:

1961. *Citrate of Potassa* is very soluble, deliquescent, and difficultly crystallizable. It is much used in medicine as a mild diaphoretic, and is the *Salt of Riverius* of old pharmacy.

Of Soda.

1962. *Citrate of Soda* is difficultly crystallizable in hexaëdral tables, of a saline flavour, and soluble in somewhat less than two parts of cold water.

Of Lime.

1963. *Citrate of Lime* has been adverted to in the preparation of citric acid. It is nearly tasteless, and scarcely soluble in water, but readily soluble in solution of citric acid: when moistened it soon grows mouldy if exposed to air. It consists of 1 proportional acid, and 1 lime.

The remaining citrates are of little importance.

V. MALIC ACID.

Whence obtained.

1964. The existence of a peculiar acid in the juice of apples, was shown by Scheele, in 1785. He obtained it by adding solution of acetate of lead to the expressed juice of unripe apples, by which a *malate of lead* was formed, and afterwards decomposed by sulphuric acid. Vauquelin obtained it by a similar process from the juice of the *house-leek*. The same acid exists, according to Braconnot, in the berries of the *mountain-ash*, from which it was first obtained by Mr Donovan in 1815, and called by him *sorbic acid*; the apparent differences between the malic and sorbic acids, are referable to the impurities of the former. Mr Donovan has given the following process for its pre-

Process. paration.* Express the juice of the ripe berries, and add solution of acetate of lead, filter, and wash the precipitate with cold water, then pour boiling water upon the filter, and allow it to pass through the precipitate into glass jars; after some hours crystals are deposited, which are to be boiled with 2,3 times their weight of sulphuric acid, specific gravity 1,090. The clear liquor is to be poured off, and, while still hot, a stream of sulphuretted hydrogen is to be passed through it, to precipitate the remaining lead; the liquid is then filtered, and when boiled so as to expel the sulphuretted hydrogen, is a solution of the pure vegetable acid.

Malic acid may also be obtained by steeping sheet-lead in the juice of apples; in a few days, crystals of malate of lead form, which may be collected and decomposed by the very careful addition of dilute sulphuric acid.

Properties. 1965. Malic acid, when carefully prepared, is a colourless liquid, very sour, and not susceptible of crystallization. It forms crystallizable salts with many of the metallic oxides, which, however, have scarcely been examined with such precision as to enable us to determine the representative number of malic acid. A detailed account of what is known respecting them will be found in M. Braconnot's Memoir.† His analysis of the crystallized *malate of lead* gives its composition thus:

Acid	100,
Oxide of lead	157,4

Sorbic acid. 1966. The *sorbic acid*, which may now be considered as identical with the malic, was analyzed by Vauquelin, by combustion with oxide of copper, and its composition is stated to be

Carbon	28,3
Oxygen	54,9
Hydrogen	16,8
	100,

These results indicate

3 atoms of carbon	18	30,	
4 ditto of oxygen	32	53,33	
10 ditto of hydrogen	10	16,67	
	60	100.	H. 2. 208.

vi. GALLIC ACID.

1967. This acid derives its name from the *gall-nut*, whence it was first procured by Scheele. It may be obtained by the following process.

How obtained. Digest bruised galls in boiling water, with about one-sixth their weight of vellum cuttings, for some hours; then allow the mixture to cool, and filter it. Add to the filtered liquor a solution of acetate of lead, as long as it occasions any precipitate; pour the whole upon a filter, wash the precipitate with warm water, and digest it in very dilute sulphuric acid; filter, and having saturated the clear liquor with chalk, evaporate to dryness. Introduce the dry mass into a retort placed in a sandbath, and upon the application of heat a portion of water will first rise, and afterwards a crystalline sublimate of gallic acid.

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* Phil. Trans. 1815.

† Annales de Chim. et Phys. vi.

Other processes.

1968. There are many other processes for obtaining this acid, among which the following deserve notice: Moisten bruised gall-nuts, and expose them for four or five weeks, to a temperature of about 80°. A mouldy paste is formed, which is to be squeezed dry, and digested in boiling water; it then affords a solution of gallic acid, which may be whitened by animal charcoal, and which, on evaporation, yields gallic acid, crystallized in white needles.*

Boil an ounce of powdered galls in 16 ounces of water down to 8, and strain; dissolve 2 ounces of alum in water, precipitate the alumina by carbonate of potassa, and, after edulcorating it, stir it into the decoction; the next day filter the mixture; wash the precipitate with warm water, till this will no longer blacken sulphate of iron; mix the washing with the filtered liquor, evaporate, and the gallic acid will be obtained in acicular crystals.†

Properties.

1969. Gallic acid, when pure, is in whitish crystals, of a sour taste, and which exhale a peculiar smell when heated. It dissolves in about 10 parts of water at 60°, and in 2 parts at 212°. It is also soluble in alcohol and in ether. When repeatedly sublimed, this acid is altered and in part decomposed. It consists, according to Berzelius‡ of

Hydrogen	5,00
Carbon	56,64
Oxygen	38,36
	100,00

These proportions give the number 63, as the representative of gallic acid.§

Gallates.

1970. The combinations of pure gallic acid with metallic bases have scarcely been examined, and consequently we have no accurate chemical history of the *gallates*. Their solutions are all very prone to decomposition, and acquire a deep brown colour. This acid forms no precipitate in solutions of potassa or of soda, but when dropped into lime-water, baryta-water, or strontia-water, it occasions the separation of a difficultly solu-

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* Braconnot, *Annales de Chim. et Phys.* ix. 181.

† Fedler, Ure's *Dictionary*.

‡ Annals of Philosophy, vol. v.

§ Or,

Carbon . . .	6 atoms	36	57,14
Oxygen . . .	3	24	38,10
Hydrogen . .	3	3	4,76
		63	100.

M.

ble gallate of those earths. It also causes a precipitate in solutions of zirconia, glucina, and yttria.

1971. When an infusion of galls is added to certain metallic solutions, it forms precipitates composed of tannin, gallic acid, and the metallic oxide, and as these are often of different colours, the infusion is employed as a test for such metals. For the colours of the precipitates, see *Tables*.

1972. Of these compounds, the ***tanno-gallate of iron*** is of the most importance, as forming the basis of writing ink, and of black dyes.

Ink. When an infusion of galls is dropped into a solution of sulphate of iron, it produces a deep purple precipitate, which is a very long time in subsiding; it becomes black by exposure to air. In writing ink, this precipitate is retained in suspension by mucilage, and the following proportions appear the best which can be used.

Finely bruised galls, 3 ounces
Green vitriol (protosulphate of iron)
Logwood shavings
Gum arabic, of each 1 ounce
Vinegar, 1 quart

Put these ingredients into a bottle, and agitate them occasionally during twelve or fourteen days; then allow the coarser parts to settle, and pour off the ink for use.

The tendency of ink to become mouldy is much diminished by keeping a few cloves in the ink bottle, or by dissolving in each pint of the ink about three grains of corrosive sublimate.

The colour of common writing ink is apt to fade, in consequence of the decomposition of its vegetable matter; and when thus illegible, it may often be restored by washing the writing with vinegar, and subsequently with infusion of galls. Acids also destroy its colouring matter, and those inks which resist their action contain some other colouring principle, usually finely powdered charcoal. Common writing ink is, for this reason, much improved by dissolving in the quantity abovementioned about an ounce of *Indian Ink*, which is lamp-black made into a cake with isinglass.*

In dyeing black the stuff is first impregnated with a solution of the gall-nut, and afterwards the colour is brought out by the application of sulphate or acetate of iron. (1855.)†

vii. BENZOIC ACID.

1973. Benzoic acid may be obtained by sublimation from ***benzoin***, which is a resinous exudation from the ***Styrax benzoe*** of Sumatra; it also exists in the ***Balsam of Peru*** and of ***Tolu***.

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* See Dr Macculloch on Indelible Ink, &c. Brewster's *Jour*. i. 318, and *Bost. Jour*. ii. 344.

† Upon these subjects much valuable information will be found in Lewis's ***Philosophical Commerce of the Arts***, and in Aikin's ***Dictionary***.

In the ***Philos. Trans.*** for 1817 Mr Brande has described the properties of a species of galls from China, which furnish very pure gallic acid, and which, could they be abundantly obtained, would certainly prove a valuable substitute for common galls, in many of the processes in which they are employed.

How obtained.

If these substances be heated in a crucible, with a cone of paper attached to its mouth, the acid condenses in it, in fine acicular crystals which were formerly called *flowers of benzoin*. A good process for procuring this acid is that recommended by Mr Hatchett which consists in digesting benzoin in sulphuric acid, when it affords a copious sublimate of pure benzoic acid.[*] It may also be obtained by boiling a pound and a half of powdered benzoin with 4 ounces of quicklime, in 6 or 8 quarts of water. When cold the clear liquor is decanted, and the residuum again boiled in half the former quantity of water. The liquors thus obtained are boiled down to half their bulk, filtered, and mixed with muriatic acid, as long as it occasions a precipitate, from which the liquor is poured off, and when dry it is put into an earthen vessel, placed in a sand heat, and sublimed into paper cones.[†]

Characters.

1974. Benzoic acid, when it has been thus sublimed, is in the form of soft feathery crystals, and of an acrid and slightly sour taste, soluble in about 30 parts of boiling water, and very sparingly soluble in cold water. It is much more soluble in alcohol, and this solution easily furnishes it in prismatic crystals.

1975. Berzelius's analysis gives the following as the components of this acid, and of the benzoate of lead:

Composition.

Hydrogen	5,16	
Carbon	74,41	
Oxygen	20,43	
	100,00.	
Benzoic acid	100,	=193,6. H.
Protoxide of lead	93,61	

On the supposition, that neutral benzoate of lead contains an atom of each ingredient, the equivalent of benzoic acid is 119,64, or in whole numbers, 120.

Dr Ure by saturating the acid with ammonia, deduced 116 as the equivalent of benzoic acid.

1976. The compounds which this acid forms with alkaline and earthy bases are called *benzoates;* they have been described in the *Philosophical Magazine*, vol. xl. and *Ann. de Chim.* vol. ix.[‡]

Other acids.

Besides the vegetable acids which have now been described, there are a few others of considerably inferior interest and importance; namely, the

Moroxylic.

1977. *Moroxylic acid*, discovered by Klaproth, in the bark of the *morus alba*, or *white mulberry*.[§] An exudation was observed upon this bark, which proved to be a compound of a peculiar acid and lime, or a *moroxylate of lime;* its solution was decomposed by acetate of lead, and the *moroxylate of lead* thus obtained decomposed by dilute sulphuric acid, furnished a solution of moroxylic acid, which gave acicular crystals on evaporation. This acid has the taste of succinic acid; it is soluble in water and alcohol, and does not, like some of its salts, form precipitates in metallic solutions. The quantity of this acid examined by Klaproth, was so small as to leave some doubt respecting its distinct nature.

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[*] Additional Experiments on Tannin, *Phil. Trans.* 1808.

[†] In the tenth volume of Nicholson's *Journal*, Mr Brande has detailed several experiments on benzoin, and has shown the relative quantity of acid afforded by the several processes which have been recommended for obtaining it.

[‡] See also Henry, ii. 220.

[§] Nicholson's *Journal*, vii.

Boletic. 1978. *Boletic acid* was obtained by Braconnot from the *boletus pseudoignarius*[*] by cautiously evaporating its expressed juice to the thickness of sirup, digesting it in alcohol, dissolving the residue in water, and adding nitrate of lead to the aqueous solution; the precipitate washed and diffused through water, was decomposed by sulphuretted hydrogen; the liquor was then filtered and evaporated till it formed crystals, which were purified by solution in alcohol and evaporation. These crystals are boletic acid; they are prismatic, and require 180 parts of water at 68°, and 45 of alcohol for their solution, which reddens blues and precipitates nitrate of lead, and the salts containing the peroxide, but not those of the protoxide of iron. This acid sublimes with little alteration, when heated. Braconnot has examined the *boletates of ammonia*, *potassa*, *lime*, and *baryta*, but his researches have not as yet been confirmed by any other chemist.[†]

Fungic. 1979. *Fungic acid* was procured by the same chemist from the *boletus juglandis*, and some other fungi; it is deliquescent and uncrystallizable.[‡]

Kinic. 1980. *Kinic acid*[§] was discovered by Vauquelin, in *Cinchona*. When a strong cold infusion of this bark is set aside, crystals of *kinate of lime* are sparingly deposited by it, which may be decomposed by oxalic acid. The kinic acid is crystallizable, sour, and bitter: the *kinates* are for the most part soluble salts: it is chiefly distinguished by forming no precipitate in solutions of lead and silver.[||]

1981. In the astringent root of the *Krameria triandra*, M. Peschier has announced the existence of what he considers as a distinct substance, which he calls *krameric acid*.[¶]

1982. M. Braconnot has given the term *Ellagic acid* (from the word *galle* reversed) to an acid body which he has detected along with gallic acid, in infusion of galls, but its characters have been but imperfectly ascertained.

Zumic. 1983. *Zumic acid* was discovered by the same chemist in vegetable substances, which have undergone acetous fermentation.[**]

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[*] Ann. de Chim. lxxx.

[†] Thomson's *System*, 6th edit. ii. 157.

[‡] Ann. de Chim. lxxxvii.

[§] Mr Brande proposes the term *cinchonic acid* as preferable. *Man. of Phar.* 64.

[||] Ann. de Chim. lix.

[¶] Journal de Pharmacie, vi.

[**] Thomson's *System*, vol. ii. p. 189.

SECTION XVII. *Of the Parts of Plants.*

1984. IN the preceding Sections the principal proximate component of vegetables have been described, and the composition of some of their detached parts has been adverted to; such of these as have not been previously noticed and as have been examined with any degree of precision, remain to be described in this Section under the heads of

Roots.
Barks.
Woods.
Leaves.
Flowers.
Seeds.
Fruits.
Bulbs.
Lichens.
Fungi.

i. ROOTS.

Ipecacuanha.

1985. *a. Ipecacuanha.* This root is the produce of the *Callicocca Ipecacuanha.** It has been examined by M. M. Pelletier and Majendie, and an account of their researches is published by M. Robiquet, in the *Annales de Chimie et Phys.* iv. 172. 100 parts of this root deprived of the woody fibre which traverses its centre afforded

Fatty matter	2	Woody fibre	48
Emetine	14	A trace of wax	
Gum	16	Loss	2
Starch	18		100

The means of separating the emetic principle have already been described. (1837.)

Valerian.

1986. *b. Valerian,* the root of the *Valeriana officinalis,* has been examined by Trommsdorf.† The recent root loses about three-fourths its weight in drying. It affords, when distilled with water, an aromatic volatile oil; it also contains starch, gum, resin, and extractive.

Turmeric.

1987. *c. Turmeric* is the root of the *Curcuma longa,* a plant cultivated in the East Indies, and used as a condiment, especially in *Curry powder.* Digested in water or alcohol, it furnishes a large proportion of yellow colouring matter, which would be very useful to the dyer, could it be rendered permanent. Most of the acids render it paler, and the alkalies change it to a deep brick-red; hence its use as a test of the presence of alkaline matter. It is also reddened by boracic acid, and by muriatic acid gas.

Madder.

1988. *d. Madder* is the root of the *Rubia Tinctorum,* and is an article of great importance in dyeing; it grows wild in most parts of the south of Europe, and is largely cultivated in some parts of Holland and the Levant; its red colour is apt to be injured by drying, a process requiring much caution. Good madder has a strong and peculiar smell; it exhibits, when cut, a cortical and a woody part of a red colour, intermixed in the former with yellow spots. The red portion is most soluble.*

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* Linnæan *Trans.* vi.

† Ann. de Chimie, lxx.

Rhubarb.

1989. *e. Rhubarb* is the root of the *Rheum palmatum*, largely cultivated in the northern parts of China; its colour is brown, with streaks of red and white. The following are the component parts, separable from the finest kinds of Turkey rhubarb.†

Water	8,2	Phosphate of lime	2,0
Gum	31,0	Malate of lime	6,5
Resin	10,0	Woody fibre	16,3
Extract, tan, and gallic acid	26,0		

Liquorice.

1990. *Liquorice*, the root of the *Glycyrrhiza glabra*, has been examined by M. Robiquet, who found in it the following substances.‡

i. Starch.
ii. Gluten.
iii. Liquorice sugar.
iv. Phosphate and malate of lime and magnesia.
v. An acrid oil.
vi. A crystallizable substance resembling asparagin.
vii. Woody fibre.

The sugar is soluble in water and in alcohol, but not convertible into alcohol by fermentation; nor into oxalic acid by the action of nitric acid.

Jalap.

1991. *Jalap*, the root of the *Convolvulus Jalappa*, is employed in medicine as a cathartic. It is imported from South America. It has not been submitted to any accurate chemical analysis, but its activity is generally regarded as chiefly resident in its resin. The finest and densest jalap affords about 12 per cent. of resin, when digested in alcohol; water takes up about 30 or 35 per cent of the remainder, and the residue appears to be inert woody fibre.

Gentian.

1992. *Gentian* is the root of the *Gentiana lutea*; according to Mr Henry§ it contains the following substances:

i. A substance resembling bird-lime.
ii. A resin combined with an oil, which gives to gentian its peculiar odour.
iii. A bitter extractive principle.
iv. Gum and colouring matter.
v. Phosphate of lime.

ii. BARKS.

Cinchona.

1993. *a. Cinchona.* The varieties of Peruvian bark have been examined by M. M. Pelletier and Caventou. In the *cinchona lancifolia*, or *pale bark*, they found the following constituent parts:

i. Cinchonia, combined with kinic acid.
ii. Green fatty matter.
iii. Red and yellow colouring matter.
iv. Tannin.
v. Kinate of lime.
vi. Gum.
vii. Starch.
viii. Lignin.

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* Aikin's *Dictionary*. Art. Dyeing. Berthollet, *Elem. de Teinture*, ii.

† Brande, *Quarterly Journal of Science and the Arts*, x. 291.

‡ Ann. de Chim. lxx.

§ Annals of Philosophy, xvi. 89.

Cinchonia, how obtained.

1994. *Cinchonia* may be obtained by the following process. A pound of pale bark (*cinchona lancifolia*) bruised small, is to be boiled for a quarter of an hour in three pints of a very dilute solution of pure potassa. The liquid, after being suffered to cool, is then to be strained through a fine cloth with pressure, and the residuum repeatedly washed and pressed. The bark, thus washed, is to be slightly heated in a sufficient quantity of water, adding muriatic acid gradually until litmus paper is slightly reddened. When the liquid is raised nearly to the boiling point, it is to be strained, and the cinchona again pressed. To the strained liquor, while hot, add an ounce of sulphate of magnesia, and after this add solution of potassa, till it ceases to occasion any precipitate. When the liquor is cold, collect the precipitate on a filter, wash and dry it, and dissolve it in hot alcohol. On evaporation of the alcohol, the cinchonia crystallizes in delicate prisms.

Properties.

1995. Cinchonia thus obtained is white, translucent, crystalline, and soluble in 2500 times its weight of boiling water, but a considerable part separates on cooling. Its taste is bitter, though long in being developed, owing to its insolubility; but its acid solutions have a strong taste of Peruvian bark. It is neither fusible nor volatile at moderate temperatures. It is very soluble in alcohol and ether, and sparingly so in fixed and volatile oils.

1996. Cinchonia restores the colour of litmus, which has been reddened by an acid; unites with all the acids; and, with the greater number, forms compounds which are perfectly neutral. The sulphate is very soluble, has an intensely bitter taste, and crystallizes in four-sided prisms. The muriate is still more soluble in water than the sulphate; dissolves in alcohol; and crystallizes in delicate prisms. The nitrate is not crystallizable. The oxalate, tartrate, and gallate of cinchonia are insoluble. Hence it is that infusion of galls precipitates the decoction of cinchonia.* H. 2. 287.

Quinia.

1997. In the *yellow* bark (*cinchona cordifolia*) M. M. Pelletier and Caventou discovered a salifiable base, which is termed *Quinia*. It may be prepared by a process similar to that above described for the preparation of cinchonia. When dried it is a white porous mass, incapable of crystallization; in water it is as insoluble as cinchonia but is much more bitter; it is however, very soluble in ether. Quinia is distinguished from cinchonia, by its smaller capacity of saturation, 360 parts of it being required to neutralize the same quantity of acid as 315 of cinchonia.

Sulphate

1998. *Sulphate of Quinia.* This salt is considered as the most active form of the salifiable principle of bark and may be prepared by the following process of M. Henry. The bark is reduced to powder, and boiled twice for about a quarter or half an hour in 14 or 15 pints of water, two ounces of sulphuric acid being added to it each time. The decoctions contain the sulphate of quinia, are of a reddish colour, which gradually acquire a yellow tint, and have a very strong bitter taste. They are to be filtered through a linen cloth, and about half a pound of pulverized quicklime is to be gradually added to the solution: the sulphate of quinia is decomposed, the alkali being precipitated along with the sulphate of lime. This is digested repeatedly in rectified alcohol, till it no longer imparts any bitter taste to this fluid; the alcoholic solutions are then evaporated till a very bitter, brown viscid substance is obtained, which becomes brittle as it cools. This is the quinia separated from almost all the other ingredients of the bark; and by digesting it in dilute sulphuric acid, a solution of the sulphate of quinia is obtained, which crystallizes on evaporation.

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* See Ann. de Chim. et Phys. xv. 289, 337; xvii. 273, 316; and Ann. of Philos. N. S. ii. 316.† H. 2.

† *Nitrate of Cinchonia* appears to be uncrystallizable. Gallic, oxalic, and tartaric acids form difficultly soluble salts with cinchonia; the precipitate occasioned by dropping tincture of galls into infusion of pale bark is a *gallate of Cinchonia.*

Two lbs of bark yield from 5 to 6 drachms of the sulphate. It consists of 100 quinia + 10,9 acid.

Acetate.

1999. *Acetate of Quinia* forms bundles of flat acicular crystals, while the corresponding salt of cinchonia crystallizes in small tables. The *gallate*, *oxalate* and *tartrate of quinia*, are nearly insoluble, but quinia is very soluble in sulphuric ether.

2000. In the *red bark* (*cinchona oblongifolia*) the two salifiable bases above described are found united.*

2001. *b.* The bark of the *horse chestnut* (*Æsculus hippocastanum*,) has been partially examined by M. Henry.‡ It appears to contain scarcely any resin; water and diluted alcohol dissolve nearly the whole of its soluble contents, which are chiefly extractive and mucilage. Tincture of galls does not render its infusion turbid, it does not therefore probably contain the peculiar substances discovered in Peruvian bark.

iii. WOODS.

Brazil wood.

2002. *a. Brazil Wood* is the produce of the *Cæsalpina crista*, growing in Brazil, in the Isle of France, Japan, and other countries: the wood is hard and heavy, and though pale when recent, it acquires a deep red colour by exposure. Digested in water it affords a fine red infusion, of a sweetish flavour; the residue, which appears nearly black, imparts much of its colour to alkaline liquors. With alcohol it gives a deep red tincture: alkalies and soap convert its red colour to a fine

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* Quarterly Journal of Science and the Arts, x. 388.

† *Cascarilla*, the bark of the *Croton Eleutheria* contains, according to Trommsdorff—*Annales de Chimie*, xxii.

	Parts.
Mucilage and bitter principle	864
Resin	688
Volatile oil	72
Water	48
Woody fibre	3024
	4696

‡ Ann. de Chim. lxxvi.

purple, hence paper tinged with Brazil wood is sometimes used as a test for alkalies; acids render it yellow; alum produces a fine crimson lake with infusion of Brazil wood; muriate of tin forms with it a crimson precipitate, bordering on purple; the salts of iron give a dingy purple colour. Sulphuretted hydrogen destroys the colour of infusion of brazil wood, but it reappears on expelling the gas.[*]

2003. *b*. *Red Sandal*, or *Saunders*, is the wood of the *Pterocarpus santalinus*, a native of several parts of India. Its deep red colouring matter is insoluble in water, but readily soluble in alcohol; it is chiefly employed for colouring a few pharmaceutical tinctures. The insolubility of its colouring principle in water furnishes a ready mode of distinguishing between it and brazil wood; and its solubility in alcohol renders it probable that it is of a resinous nature. Sandal wood.

2004. *c*. *Logwood*, the produce of the *Hæmatoxylon campechianum*, has already been noticed as containing a peculiar colouring principle. (1827.) It imparts a fine purple or crimson colour to pure water, but its tint is altered by the slightest metallic impregnation; alkalies deepen it, and acids render it paler; alum forms with it a violet-coloured lake; sulphate of iron renders the infusion of logwood deep purple, or nearly black; sulphate of copper and acetate of lead throw down brown and purple precipitates; and muriate of tin precipitates the whole of the colouring matter, in the form of a purple compound. The colours which logwood produces are for the most part very perishable.[†] Logwood.

iv. LEAVES.

2005. *a*. *Senna*. According to Lagrange[‡] the leaves of the *Cassia senna* are characterized by containing a peculiar extractive principle, which, by long boiling, passes into a resinous substance, in consequence of absorbing oxygen; they also contain a resin which resists the action of water, and is soluble in alcohol; the whole of the soluble matter amounts to about one-third the weight of the senna. In the *London Medical Repository*, vol. xv. 169, the effects of the various re-agents on infusion of senna are detailed by Mr Batley. Senna.

2006. *b*. *Nightshade*. The leaves of the *Atropa Belladonna* contain according to Vauquelin[§] Nightshade.

i. Vegetable albumen.
ii. A bitter narcotic principle.
iii. Nitrate, muriate, sulphate, binoxalate, and acetate of potassa.

Dr Brandes has announced the existence of a new vegetable alkali in this plant, which he calls *atropia*. It forms brilliant acicular crystals, tasteless, and difficultly soluble in water and alcohol. It affords distinct salts with the acids; the *Sulphate of Atropia* consists of

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[*] Chevreuil, *Ann. de Chim.* lxvi.

[†] Bancroft *on Permanent Colours*, ii. 338. Chevreuil, *Ann. de Chim.* lxvi. 254.

[‡] Ann. de Chim. xxvi.

[§] Ann. de Chim. lxxii.

Sulphuric acid	36,52
Atropia	38,93
Water	24,55
	100,00

Henbane.

2007. *c. Hyoscyamus Niger*, or *Henbane*. In the leaves of this plant Dr Brandes has also ascertained the presence of a peculiar and highly poisonous salifiable base which he calls *hyosciama*. With the acids it forms characteristic salts; it crystallizes in long prisms.

Lupulin.

2008. *Lupulin* was discovered by Dr Ives* and M. M. Payen and Chevalier, about the same time, in the leaves of the *Humulus Lupulus* or common hop. It is extremely bitter, of a yellow colour, and has an aromatic odour. It is the principle on which the characteristic properties of the hop depend.

v. FLOWERS.

Colouring matter of flowers.

2009. The colouring matter of most flowers is extremely fugitive, and is generally much changed by mere exsiccation. They usually communicate their colour to water; the infusion of blue flowers is generally reddened by acids, and changed to green or yellow by alkalies; that of yellow flowers is made paler by acids, and alkalies render it brown; the red infusion of many flowers is exalted in tint by acids, and changed to purple, and in some instances, to green by alkalies.

It is probable that one and the same principle gives colour to several of the blue and red flowers, but that the presence of acid in the latter produces the red; the petals of the red rose, triturated with a little carbonate of lime and water, give a blue liquor; alkalies render it green, and acids restore the red.

2010. A colouring matter analogous to that of the violet, exists in the petals of red clover, in the red tips of those of the common daisy, of the blue hyacinth, the holly-hock, lavender, in the inner leaves of the artichoke, and in numerous other flowers; reddened by an acid, it colours the skin of several plums, and the petals of the scarlet geranium and pomegranate. Some flowers which are red, become blue by merely bruising them; this is also the case with the colouring matter of red cabbage leaves, and of the rind of the long radish. Mr Smithson has suggested that the reddening acid is in these cases the carbonic, which escapes on the rupture of the vessels which enclose it.

2011. The petals of the common *corn-poppy*, rubbed upon paper, give a purple stain, little altered by ammonia or carbonate of soda, but made green by caustic potassa. The infusion of poppy-petals in very dilute muriatic acid, is florid red ; chalk added, renders it of the colour of port wine ; carbonate of soda in excess gives the same colour, but excess of potassa changes it to green and yellow. The expressed juice of the black mulberry possesses nearly the same properties.*

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* American Journal of Science, ii.

2012. The flowers of the *carthamus tinctorius*, or *safflower*, cultivated chiefly in Spain and the Levant, contain a yellow colouring matter, easily soluble in water, and a red, soluble in alcohol and weak alkaline liquors ; the latter only is employed. *Rouge* is the red colouring matter of the carthamus, obtained by digesting the washed flowers in solution of carbonate of soda, and adding lemon juice, which throws it down in the form of a fine powder, which is dried and mixed with a portion of powdered talc ; carthamus is also used for dyeing silk. The details of the analysis of carthamus will be found in the *Essays of* Dufour and Marchais.†

Rouge.

Pollenin.

2013. *Pollenin* is prepared from the pollen of tulips and was discovered by Dr John. It is distinguished by its insolubility in all those agents which are usually employed to effect the solution of other vegetable products, and is highly inflammable, burning rapidly with a large flame. When exposed to the air it soon passes to a state of putrefaction ; and by destructive distillation, ammonia is disengaged, along with some of the usual products that arise from the decomposition of animal matter.‡

vi. SEEDS.

2014. Starch is an essential component of the greater number of seeds, and it is generally united in them with a variable portion of gluten, and often of fixed and of volatile oil. The component parts of wheat-flour, and of several esculent grains, have already been stated (1818,) and a variety of curious details respecting them will be found in EINHOFF's *Papers*, in GEHLEN's *Journal*.

Sir H. Davy has also examined a number of seeds with a view to determine their relative nutritive powers : for the results of his experiments see *Agricultural Chemistry*, 4to. 131.

Almonds.

2015. *Almonds*, the seeds of the *amygdalus communis*, consist of an albuminous substance and oil ; the latter may be obtained by expression, five pounds yielding about one pound of cold drawn oil, and about a pound and a half when aided by heat. The bitter almond affords by pressure an oil analogous to that from the former; but if the expressed cake be distilled with water, a portion of volatile oil eminently poisonous, and smelling strongly of the almond, is obtained; this oil is used as a flavouring material by confectioners, and by the manufacturers of noyau. In the *Philosophical Transactions* for 1811, Mr Brodie has detailed a variety of experiments illustrative of its action as a poison, in which, as well as from its odour it appears identical nearly with hydrocyanic acid.

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* Smithson, *Phil. Trans*. 1818, 110.

† Ann. de Chim. xlviii.

‡ *Chlorophylle* is a term which is applied to the green colouring matter of plants, and is obtained by subjecting the green parts, especially the leaves, to pressure along with water, treating the residue with alcohol, and evaporating the solution. It is purified from a brown colouring matter by warm water. It is soft, viscid, and of a fine green colour, soluble in sulphuric acid without being decomposed, and is precipitated by water and solutions of the alkalies. It is very soluble in alcohol and ether, but is sparingly dissolved by water.

2016. The seeds of the *white lupine* (*lupinus albus*) contain, according to Fourcroy and Vauquelin,* gluten and a green acrid oil, with a considerable portion of phosphate of lime and magnesia, but no starch or sugar.

Coffee.

2017. *Coffee*, the seed of the *Coffea Arabica* has been examined both in its raw and roasted state. From 64 parts of raw coffee,† Cadet obtained

Gum	8,
Resin and bitter extract	2,0
Gallic acid	3,5
Insoluble matter	43,5
Loss including a trace of albumen	7,0
	64.

Hermann has given the following comparative analysis of coffee from the Levant and from Martinique‡, the results of which differ much from those of Cadet:

	Levant.	Martinique.
Resin	74	68
Extractive	320	310
Gum	130	144
Fibrous matter	1335	1386
Loss	61	12
	1920	1920

When coffee is roasted it undergoes a peculiar change of composition attended by the formation of tan, and a volatile, fragrant, and aromatic principle; but in this state it has not been examined with any precision.

Cafeine.

2018. *Cafeine* is a new principle which was discovered in coffee by Robiquet. It is white, volatile, and crystallizable, and is particularly distinguished by the large quantity of nitrogen which it contains, being greater than that in almost any other vegetable. According to Dumas and Pelletier, it consists of 27,14 oxygen, 4,81 hydrogen, 46,51 carbon, and 21,54 nitrogen.

Pepper.

2019. *Pepper*. The seed of the *piper nigrum* has not been satisfactorily analyzed: it imparts its acrimony to alcohol and to water; it contains a species of volatile oil, with starch and extractive matter.§

Piperin.

2020. *Piperin* is extracted from black pepper, by digesting it in alcohol, evaporating the solution, treating the residue with water as long as this liquid dissolves any portion of it, and then dissolving it in alcohol. This solution affords prismatic crystals of piperin, which may be rendered transparent and colourless by repeated solution and crystallization. They are soluble in alcohol and ether, and are insipid. The peculiar properties of pepper appear to depend on an acrid volatile oil which is associated with it.

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* Ann du Muséum, No. xxxvi.

† Ann. de Chim. lviii.

‡ Crell's *Annales*, ii.

§ Nicholson's *Journal*, ii.

Mustard.

2021. *Mustard.* The seed of the *sinapis nigra* derives its acrimony from volatile oil; it also contains a tasteless fixed oil, albumen, gum, and traces of sulphur and earthy salts.

2022. The seeds of the *lycopodium clavatum*, or *common club moss* have been analyzed by Bucholz.* From 1000 parts he obtained

Fixed oil	60
Sugar	30
Mucilage	15
Insoluble residue	895
	1000

This seed has the appearance of a fine yellow powder, which deflagrates when projected into the flame of a candle; it is used in theatres to imitate lightning; and the German apothecaries employ it to prevent the adhesion of pills.

Annotta.

2023. *Annotta* is the produce of the *bixa orellana*, a tree cultivated in various parts of America. When the capsules are ripe, the seeds are bruised and steeped for several weeks in water, until converted into a pulp, which is allowed to putrefy, and being diffused through a fresh portion of water, is heated till a scum rises, which is successively removed as it forms, and being carefully dried, is made up into cakes, and wrapped in palm leaves for exportation.

Annotta is soluble in water and alcohol; the solutions have a disagreeable smell, and are of an orange colour; alkalies render it more soluble and increase its colour; alum and the acids separate it from its solutions in the form of a yellow sediment; it is used for dyeing silk and colouring cheese.

Citisin.

2024. *Citisin* was discovered by M. M. Payen and Chevalier in the seeds of the *Cytisus Laburnum.* Its colour is yellow, and it has a disagreeable taste; it is soluble in water, alcohol and ether. It is easily decomposed by heat, and the strong acids produce the same effect.

vii. FRUITS.

Their contents.

2025. The acid matter contained in fruits is either the tartaric, oxalic, citric, or malic; or a mixture of two or more of them; but the nature and proportion of the acid varies at different periods of their growth; gluten and starch are found in some fruits, and a gelatinizing substance, which has sometimes been regarded as identical with animal jelly, but which is probably a compound of gum and one or more vegetable acids.

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* Gehlen's *Journal*, vi.

Fruits contain sugar.

2026. Most of our common fruits also contain sugar, and it exists in all those the juice of which is susceptible of vinous fermentation. In some fruits the quantity of sugar is increased by mashing and exposure to air; this is remarkably the case with some of the rough-flavoured apples used for cider, the pulp of which becomes brown, and at the same time sweet by a few hours' exposure.

Colouring matter.

2027. The colouring matter of fruits seems in most cases to bear a strong resemblance to that of flowers. The red juice of the mulberry was found to exhibit the same characters as the colouring principle of the wild poppy; carbonated alkalies render it blue, but caustic potassa changes it to green and yellow: the juice of red currants, cherries, elder berries, and privet berries, and the skin of the buckthorn berry, appear to contain a similar colouring principle.

Sap green.

2028. The unripe berries of the buckthorn furnish a juice, which, when inspissated, is known under the name of *sap green*. It is soluble in water, and rendered yellow by carbonate of soda and caustic pôtassa; the acids redden it, and carbonate of lime restores it to green, which is therefore probably the proper colour of the substance.[*]

Elaterium.

2029. The fruit of the *wild cucumber* (*cucumis elaterium*) furnishes a very acrid juice, which deposits the powerful cathartic known under the name of *elaterium*. This substance occurs in commerce in thin cakes, of a greenish colour and bitter taste; it derives its cathartic power from a small portion of a very active principle, which Dr Paris has called *Elatin*:[†] from 10 grains of elaterium he obtained

Water	0,4
Extractive	2,6
Fecula	2,8
Gluten	0,5
Woody matter	2,5
Elatin Bitter principle	1,2
	10.

Zeine.

2030. *Zeine* was discovered by Prof. Gorham in the *Zea Mays* or indian corn. It may be procured by infusing the grain in water, filtering, and digesting the insoluble residue in alcohol, and evaporating to dryness. It is of a yellowish colour, insipid, soft and elastic.[‡]

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[*] Smithson, *Phil. Trans.* 1818, p. 116.

[†] Pharmacologia 223, 3d edit.

[‡] N. E. Journal of Medicine.

viii. BULBS.

2031. The *potato*, which is the bulbous root of the *solanum tuberosum*, has been examined by Dr Pearson and by M. Einhoff; from 100 parts, the latter chemist obtained Potato.

Starchy matter	22
Albumen and mucilage	5,4
	27,4

The average quantity of nutritive matter contained in the potato, amounts to about one fourth its weight. When potatoes become sweet by exposure to frost, a portion of mucilage passes into the state of sugar, for Einhoff found the quantity of starch undiminished.

2032. *Garlic* or the bulbous root of the *allium sativum*, has been examined by Cadet.[*] It loses by drying about two-thirds of its weight; its juice is viscid, and very slightly sour; it yields coagulated albumen when heated, and when distilled with water furnishes an acrid oil having a strong odour of garlic. Garlic.

2033. The bulb of the *Allium Cepa*, or *Onion*, has been analyzed by Fourcroy and Vauquelin.[†] The juice of this root, when exposed to a temperature of about 70°, forms a quantity of vinegar, and deposits a sediment having the characters of gluten combined with oil and sulphur. In the acetous solution is contained a substance having the properties of manna, and which is probably a product of the fermentation, for none could be detected in the recent juice. Onion.

2034. *Squill*, the bulbous root of the *Scilla maritima* contains, according to Vogel,[‡] a peculiar bitter principle, which he terms *Scillitin*, combined with gum, and a considerable portion of tannin.

ix. LICHENS.

2035. There are several lichens which abound in colouring matter; of these the most remarkable is the *Lichen rocella*, which grows in the South of France and in the Canary Islands, and which affords the beautiful but perishable blue called *litmus*, *archil*, or *turnsole*. Archil. The moss is dried, powdered, mixed with pearlash and urine, and allowed to ferment, during which it becomes red, and then blue; in this state it is mixed with carbonate of potassa and chalk, and dried. It is used for dyeing silk and ribands, and by the chemist as a most delicate test of acids, which it indicates by passing from blue to red; the blue colour is restored by alkalies, which do not render it green. *Cudbear* appears to be a similar preparation of the *lichen tartareus*.[§]

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[*] Ann. de Chim. lix.

[†] Ann. de Chim. lxv.

[‡] Ann. de Chim. lxxxiv.

[§] Bancroft on Colours, i. 300.

Mr Smithson has thrown some doubt upon the use of alkalies in the precipitation of litmus, for he found its tincture produce no change on solutions of muriate of lime, nitrate of lead, muriate of platinum and oxalate of potassa; he at the same time suggests the idea of its being a compound of a vegetable principle with potassa.*

Iceland moss. 2036. The *Lichen Islandicus*, or *Iceland Moss* has been subjected to analysis by Berzelius.† He obtained from it the following substances:

Sirup	3,6
Bi-tartrate of potassa Tartrate of lime Phosphate of lime	1,9
Bitter principle	3,0
Wax	1,6
Gum	3,7
Colouring extract	7,0
Starch	44,6
Insoluble starchy matter	36,6
	102,0

x. FUNGI OR MUSHROOMS.

2037. M. Braconnot who has lately examined many fungi with minute attention, has given the name *fungin* to the insoluble spongy portion which they contain, and which in many respects resembles lignin: he has also detected in them two peculiar acids, which he terms *fungic acid* (1979) and *boletic acid* (1978); the method of extracting which has been above described. A peculiar fatty matter, or adipocer, has been found by Vauquelin and Braconnot, in several of the fungi; an albuminous substance, and salts, some of which are boletates and fungates, have also been detected in them, but the analyses are too abstruse, and the results too complicated, to be regarded as perfectly satisfactory.‡

Fungic acid.

SECTION XVIII. *Phenomena and Products of Fermentation.*

Fermentation. 2038. THE term *fermentation* is employed to signify the spontaneous changes, which certain vegetable solutions undergo, placed under certain circumstances, and which terminate either in the production of an intoxicating liquor, or of vinegar; the former termination constituting *vinous*, the latter *acetous* fermentation.

Vinous and acetous.

The principal substance concerned in vinous fermentation is sugar; and no vegetable juice can be made to undergo the process, which does not contain it in a very sensible quantity.

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* Phil. Trans. 1818, p. 112.

† Ann. de Chim. xc.

‡ Ann. de Chim. lxxix. lxxxv. &c.

In the production of beer, the sugar is derived from the malt; in that of wine, from the juice of the grape.

Beer.

2039. In the manufacture of *beer*, the malt is ground and infused in the *mash-tun*, in rather more than its bulk of water, of the temperature of 160° or 180°. Here the mixture is stirred for a few hours; the liquor is then run off, and more water added, until the malt is exhausted. These infusions are called *wort*, and its principal contents are *saccharine matter*, *starch*, *mucilage*, and a small quantity of *gluten*. The strength of the wort is adjusted by its specific gravity, which is usually found by an instrument, not quite correctly called a *saccharometer*, since it is influenced by all the contents of the wort, and not by the sugar only.*

The wort is next boiled with hops, amounting upon the average, to $\frac{1}{10}$ the weight of the malt, their use being to cover the sweetness of the liquor by their aromatic bitter, and to diminish its tendency to acidify. The liquor is then thrown into large, but very shallow, vessels, or *coolers*, where it is cooled to about 50°, as quickly as possible; it is then suffered to run into the *fermenting vat*, having been previously mixed with a proper quantity of *yeast*, which accelerates fermentation, apparently by virtue of the gluten which it contains.

In the fermenting vessel, the different substances held in solution in the liquor begin to act upon each other; an intestine motion ensues, the temperature of the liquor increases, carbonic acid escapes in large quantities; at length this evolution of gas ceases, the liquor becomes quiet and clear, and it has now lost much of its sweetness, has diminished in specific gravity, acquired a new flavour, and become intoxicating.

2040. The distillers prepare a liquor, called *wash*, for the express purpose of producing from it ardent spirits; instead of brewing this from pure malt, they chiefly employ raw grain, mixed with a small quantity only of malted grain; the water employed in the mash-tun is of a lower temperature than that requisite in brewing, and the mashing longer continued; by which it would appear that a part of the starch of the barley is rendered into a kind of saccharine matter. The wort is afterwards fermented with yeast.

Wine.

2041. *Wine* is principally procured from the juice of the grape, and some other saccharine and mucilaginous juices of fruits. The principal substances held in solution in grape juice are, *sugar*, *gum*, *gluten*, and *bi-tartrate of potassa*. It easily ferments spontaneously at temperatures between 60° and 80°, and the phenomena it gives rise to closely resemble those of the wort with yeast. After the operation, its specific gravity is much diminished, its flavour changed, and it has acquired intoxicating powers.[*]

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* It is a brass instrument, of the shape shown in fig. 126, so adjusted in weight as to sink to the point marked 0°, in distilled water, at the temperature of 70°, and when immersed in a liquor of the same temperature, and of the specific gravity of 1,100, it is buoyed up to the mark 100, just above the bulb. The intermediate space is divided into 100 equal parts, and consequently will indicate intermediate degrees of specific gravity. This is the most useful form of the instrument, though not that in common use. The specific gravity of the wort for ale is usually about 1,090 to 1,100, and for table-beer from 1,020 to 1,030

2042. If a mixture of 1 part of sugar, 4 or 5 of water, and a little yeast, be placed in a due temperature, it also soon begins to ferment, and gives rise to the same products as wort or grape-juice; and, as the free admission of air is not necessary to vinous fermentation, its results may easily be examined by suffering the process to go on in the apparatus, fig. 127, consisting of a matrass containing the fermenting mixture, with a bent tube issuing from it, and passing into an inverted jar standing in water.

Gaseous products of fermentation. It will thus be found that the only gaseous product is carbonic acid; and consequently, that carbon and oxygen are the principles which the saccharine matter loses during the process.

2043. When any of the above-mentioned fermented liquors are distilled, they afford a *spirituous liquor;* that from wine is termed *brandy;* from the fermented juice of the sugar-cane we obtain *rum;* and from wash, *malt spirit;* and these spirituous liquors, by re-distillation, furnish *spirit of wine, ardent spirit*, or *alcohol.*

2044. The different fermented liquors furnish very different proportions of alcohol, and it has been sometimes supposed that it does not pre-exist to the amount in which it is obtained by distillation; but some experiments made by Prof. Brande upon the subject, in 1811 and 1813, and which are printed in the *Philosophical Transactions* for those years, tend to show that it is a real educt, and not formed by the action of heat upon the elements existing in the fermented liquor.[†]

2045. The principle upon which the intoxicating properties of fermented liquors depends, and which exists in ardent spirits, Alcohol. is in its purest form called *alcohol.* It may be obtained by distilling the *rectified spirit of wine* of commerce, with one-fourth of its weight of dry and warm carbonate of potassa; about three-fourths may be drawn over. There are other substances which may be used as substitutes for the carbonate, especially muriate of lime.

2046. It has been found also that spirit of wine of sp. gr. 867 when inclosed in a bladder, and exposed for some time to the air, is converted into alcohol of sp. gr. 0.817, the water only escaping through the coats of the bladder.[‡]

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[*] The vegetable extract existing in the recent or expressed juice of the grape, is considered by Dr Macculloch and M. Thenard as the proper fermentative principle. The last of these chemists supposes that this extract tends to excite fermentation in consequence of its having the power of abstracting, by means of its hydrogen and carbon, a portion of oxygen from the sugar of the must. In this way the divellent affinities of the ingredients of the sugar are brought into action. A part of its oxygen and carbon is evolved in a gaseous form, while its hydrogen and the remaining oxygen and carbon are converted into alcohol.—Brewster's *Jour.* 1. 164.

[†] For the proportion of alcohol existing in several kinds of wine and other liquors, see *Tables.*

[‡] Quart. Jour. viii. 381, and Henderson's *History of wines,* Lond. 1824.

2047. Alcohol obtained by slow and careful distillation, is a limpid, colourless liquid, of an agreeable smell, and a strong pungent flavour. Its specific gravity varies with its purity; the purest obtained by rectification over muriate of lime being 791; as it usually occurs it is .820 at 60°. If rendered as pure as possible by simple distillation, it can scarcely be obtained of a lower specific gravity than .825, at 60°.

May be frozen.

2048. Dr Hutton is said to have succeeded in freezing alcohol, but the means by which he effected its congelation were never disclosed. Mr Walker exposed it to a temperature of—91 but no congelation took place. Even when diluted with an equal weight of water, it requires a cold of 6° below 0 to congeal it. By using anhydrous sulphurous acid it has been frozen by M. Bussy, (527). When of a specific gravity of ,825, it boils at the temperature of 176°, the barometrical pressure being 30 inches. In the vacuum of an air-pump it boils at common temperatures. The specific gravity of the vapour of alcohol, compared with atmospheric air, is 1,613.*

Condensation of alcohol and water.

2049. Alcohol may be mixed in all proportions, with water, and the specific gravity of the mixture is greater than the mean of the two liquids, in consequence of a diminution of bulk that occurs on mixture as may be shown by the following experiment:

Exp.

Fig. 128 represents a tube with two bulbs, communicating with each other, the upper one being supplied with a well-ground glass stopper. Fill the tube and lower bulb with water, pour alcohol slowly into the upper bulb, and when full put in the stopper. The vessel will now be completely filled, the alcohol lying upon the water; if it be inverted, the alcohol and water, will slowly mix and the condensation that ensues will be indicated by the empty space in the tube. A considerable rise of temperature takes place in this experiment, in consequence of the condensation.

Strength, how ascertained.

2050. The strength of such spirituous liquors as consist of little else than water and alcohol, is of course ascertained by their specific gravity; and for the purpose of levying duties upon them, this is ascertained by the hydrometer; an instrument constructed on the same principle as that described at page 527 (*note.*) But the only correct mode of ascertaining the specific gravity of liquids, is by weighing them in a delicate balance against an equal volume of pure water, of a similar temperature. (762.)†

2051. There are other methods of judging of the strength of spirituous liquors, which, though useful, are not accurate, such as the taste, the size and appearance of the bubbles when shaken, the sinking or floating of olive oil in it, and the appearances it exhibits when burned; if it burns away perfectly to dryness, and inflames gunpowder or a piece of cotton immersed in it, it is considered as alcohol: the different spirituous liquors leave variable proportions of water when thus burned in a graduated vessel.*

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* Gay-Lussac *Annales de Chimie et Phys.* Tom.

† In the *Philosophical Transactions* for 1794, Mr Gilpin has given a copious and valuable series of tables of the specific gravity of mixtures of alcohol and water, and of the condensation that ensues, with several other particulars. These are extremely useful, as enabling us to ascertain, without difficulty the relative quantity of alcohol contained in any mixture of known specific gravity. See *Tables*

Properties of alcohol. 2052. Alcohol is extremely inflammable, and burns with a pale blue flame, scarcely visible in bright day-light. It occasions no fuliginous deposition upon substances held over it, and the products of its combustion are carbonic acid and water, the weight of the water considerably exceeding that of the alcohol consumed. According to Saussure, jun. 100 parts of alcohol afford, when burned, 136 parts of water, the production of which may be shown by substituting the flame of alcohol for that of water, in the apparatus described in the first of the work, under the Article WATER (349), and if the tube at its extremity be turned down into a glass jar, it will be found that a current of carbonic acid passes out of it, which may be rendered evident by lime water. Pl. 4, fig. 92.

There are some substances which communicate colour to the flame of alcohol; from boracic acid it acquires a greenish yellow tint; nitre and the soluble salts of baryta cause it to burn yellow, and those of strontia give it a beautiful rose colour; cupreous salts impart a fine green tinge.

2053. Alcohol dissolves pure soda and potassa, but it does not act upon their carbonates: consequently, if the latter be mixed with alcohol containing water, the liquor separates into two portions, the upper being alcohol deprived to a considerable extent, of water, and the lower the aqueous solution of the carbonate. The alcoholic solution of caustic potassa was known in old pharmacy under the name of Van Helmont's *Tincture of Tartar*. Tincture of Tartar. Its use in purifying potassa has already been stated (825); if it be long kept it deposits small crystals of carbonate of potassa, and becomes nearly black, from the decomposition of a portion of alcohol; the greater number of sulphates are insoluble in this menstruum, but it dissolves many of the muriates and nitrates. It also dissolves the greater number of the acids. It absorbs many gaseous bodies. It dissolves the vegetable acids, the volatile oils, the resins, tan, and extractive matter, and many of the soaps; the greater number of the fixed oils are taken up by it in small quantities only but some dissolve largely. It may be remarked that many errors exist in the published estimates, of the solubility of substances in alcohol, arising from the existence of water either in the solvent or substance dissolved.

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* There is the greatest difficulty in ascertaining what is meant by the term *proof spirit*. Dr Thomson, quoting the Act of Parliament of 1762 (*System*, ii. 319,) states, that at the temperature of 60°, the specific gravity of proof spirit should be 0,916; and he also observes, that *proof spirit* usually means a mixture of *equal bulks*, of alcohol and water; but the specific gravity of such a mixture will, of course, depend upon that of the standard alcohol, which is not specified. It appears from Gilpin's *Tables*, that spirit of the specific gravity ,916 at 60°, consists *by weight* of 100 parts of alcohol, specific gravity ,825, at 60°, and 75 of water; and, *by measure*, of 100 parts of the same alcohol, and 61,87 of water. From the *Tables* of Lowitz, quoted by Dr Thomson, from Crell's *Annals* (1796, 1. 202,) we learn that equal weights of alcohol, specific gravity ,796, at 60°, (and which may be regarded as *pure alcohol*,) and water, have a specific gravity of ,917, which is very near legal proof, and which, according to Gilpin's *Tables*, contains 62,8 parts per cent. of his alcohol, *by measure*.

Decomposition.

2054. When the vapour of alcohol is passed through a red-hot copper tube, it is decomposed, a portion of charcoal is deposited, and a large quantity of carburetted hydrogen gas is evolved.

2055. The most satisfactory experiments on the composition of alcohol are those of Saussure, as quoted by Dr Thomson.* He passed the alcohol through a red-hot porcelain tube, terminating in a glass tube six feet long and surrounded by ice; all the products were carefully collected and weighed. The result of this analysis was, that 100 parts of pure alcohol consist of

Hydrogen	13,70
Carbon	51,98
Oxygen	34,32
	100,00

Composition.

These numbers approach to 3 proportionals of hydrogen = 3; 2 of carbon, = 12; and 1 of oxygen, = 8.

Or it may be regarded as composed of

Olefiant gas	61,63
Water	38,37
	100,00

If we consider it as composed of 1 volume of olefiant gas, and 1 volume of the vapour of water, the two volumes being condensed into 1, the specific gravity of the vapour of alcohol, compared with common air, will be 1,599, or, according to Gay-Lussac, 1,613.

Ether.

2056. When alcohol is submitted to distillation, with certain acids, a peculiar compound is formed, called *ether*, the different ethers being distinguished by the name of the acid employed in their preparation.

a. SULPHURIC ETHER.

Preparation.

2057. *Sulphuric Ether* is the most important of these compounds; it is prepared as follows: Equal weights of alcohol and sulphuric acid are carefully mixed and introduced into a glass retort placed in a sand-bath, to which is adapted a capacious tubulated glass globe, connected with a receiver, as represented in fig. 100. Raise the mixture in the retort to its boiling point as rapidly as possible, and, keeping the receiver cool by water or ice, continue the distillation, till opaque vapours appear in the retort; then remove the receiver, and agitate its contents with a little quick-lime; after which pour off the clear liquor, and re-distil to the amount of three-fourths its original quantity with the same precautions as before. The

Pl. 4

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* System, ii. p. 327.

nearly colourless below the ethereal solution, which is to be carefully decanted off; into this the polished steel is for an instant plunged, and immediately afterwards washed in water, or in a weak alkaline solution. Though the coating of platinum is the least beautiful, Mr Stodart, who has made many experiments upon this subject, considers it as the best protection from rust. Polished brass may be coated by the same process. These surfaces of gold and platinum, though very thin, are often a useful protection: with gold the experiment is particularly beautiful, and well illustrates the astonishing divisibility of the metal. The ethereal solution of gold is not permanent, but, after a time, deposits the metal in the form of a film, in which crystals of gold are often perceptible.

2063. Ether is sparingly soluble in water, and in alcohol it dissolves in all proportions. The *spiritus ætheris sulphurici* of the *Pharmacopœia*, is an alcoholic solution of ether.

Inflammable. 2064. Ether is highly inflammable, and in consequence of its volatility it is often kindled by the mere approach of a burning body; a circumstance which renders it highly dangerous to decant, or open vessels of ether near a candle.[*]

Exp. The inflammability of ethereal vapour may be shown by passing a small quantity into a receiver, furnished with a brass stop-cock and pipe, and inverted over water at a temperature of 100°. The receiver becomes filled with the vapour, which may be propelled and inflamed; it burns with a bright bluish white flame.

Explodes with oxygen. 2065. When ether is admitted to any gaseous body it increases its bulk. Oxygen thus expanded, produces a highly inflammable mixture; if the quantity of oxygen be large and of ether small, the mixture is highly explosive, and produces water and carbonic acid.

Exp. Into a strong two ounce phial, filled with oxygen gas, and wrapped round with a cloth, let fall a drop of ether. On applying the flame of a candle, a violent detonation will ensue.

2066. When the vapour of ether is passed through a red-hot tube, it is decomposed, and furnishes a large quantity of carburetted hydrogen gas.

2067. The results of its combustion have been minutely examined by several chemists of eminence, especially by Saussure, and Dr Ure; they have given its ultimate elements as follows:—

Analysis.

Carbon	67,98	60,00
Oxygen	17,62	26,66
Hydrogen	14,40	13,34
	100 *Saussure.*	100, *Ure.*

Saussure's ether was of the specific gravity of ,715 at 68° F. and that employed by Dr Ure only 700. On comparing these analytical results, especially Dr Ure's with the theory of vol-evaporation from surfaces, it produces intense cold, as may be felt by pouring it upon the hand; and seen, by dropping it upon the bulb of a thermometer, which sinks to many degrees below the freezing point (140). The specific gravity of the vapour of sulphuric ether, compared with atmospheric air, is according to Gay-Lussac, as 2,586 to 1,000.

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[*] In spirit warehouses or druggist's laboratories where ether is distilled, the *safety lamp* (fig. 116) may be advantageously used.

Boiling point.

At mean pressure, sulphuric ether, when of a specific gravity of ,720, boils at 98°, and under the exhausted receiver of an air-pump, at all temperatures above—20°; hence, were it not for atmospheric pressure, ether would only be known in the state of vapour.

In consequence of the cold produced during the vaporization of sulphuric ether, the phænomena of boiling and freezing may be exhibited in the same vessel. For this purpose procure a very thin flask which fits loosely into a wine-glass, as shown in fig. 129. Pour a small quantity of ether into the flask, and of water into the glass, and place the whole under the receiver of an air pump; during exhaustion, the ether will boil, and a crust of ice will gradually form upon the exterior of the flask.

Ex.

Pl. 7.

When subjected to a degree of cold equal to—46°, sulphuric ether freezes.

Dissolves resins, &c.

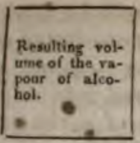
2061. Ether dissolves the resins, several of the fixed oils, and nearly all the volatile oils; it also dissolves a portion of sulphur, and of phosphorus; the latter solution is beautifully luminous when poured upon warm water, in a dark room. The fixed alkalies are not soluble in ether, but it combines with ammonia.

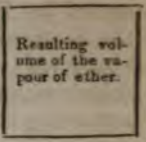
Washing of ether.

By repeated agitation with water, ether is brought to a high degree of purity, and acquires the property of dissolving caoutchouc. The process, as performed in presence of Faujas de St Fond, by Mr Winch of London, is described by the former as follows: Let a pint of good sulphuric ether be put into a bottle, or, in preference, into the separator, (fig. 130), along with two pints of water; agitate the two liquids repeatedly together; then let them stand till the ether has risen to the surface, and draw off the water through the lower cock *a*, leaving the ether in the vessel. Repeat this process three or four times, or till scarcely one-third of the ether remains, and decant the residue into a well-stopped phial. In this ether, the elastic gum, cut into thin slips, soon begins to swell; but its action is slow, and, about the end of five days, the solution is completed. The method of forming tubes, &c. with this solution is described in the first volume of Faujas de St Fond's Travels in England, chap. i. H.

Action on oxides of gold and platinum.

2062. Ether dissolves the oxides of gold and platinum, and these solutions have been employed for coating steel with those metals, with a view to ornament and as a defence from rust. If to a saturated solution of gold or platinum, in nitro-muriatic acid, there be added about three parts by measure of good sulphuric ether, it soon takes up the metals, leaving the acid





[*]

2068. When a little ether is introduced into chlorine, the gas is absorbed, and a peculiar compound results, in which muriatic acid is very perceptible; if the ether be inflamed, a large quantity of charcoal is deposited, and muriatic acid is abundantly evolved.

Oil of wine. 2069. If ether be mixed with its bulk of sulphuric acid, and submitted to distillation, a portion of it is converted into a peculiar fluid which has been termed *oil of wine;* it is the *oleum æthereum* of the *Pharmacopœia.* It has a sweetish taste, and a rich agreeable odour It does not mix with water, but readily dissolves in ether and in alcohol. It is very inflammable, and deposits a large quantity of carbon during its combustion. Its composition has not been inquired into.

Ænothionic acids. 2070. The residue of the distillation of ether has been examined by several chemists. According to Sertuerner, new acid compounds are produced, which he calls *ænothionic acids.*[†] M. Vogel, in repeating these experiments, allows the formation of one new acid only, which he calls *sulphovinous acid;* he obtained it by saturating the residue of the distillation of ether with carbonate of lead; the liquor being filtered, contained a soluble *sulphovinate of lead;* sulphuretted hydrogen passed through this solution precipitated the lead and left the pure acid, which is so easily decomposed by heat as only to admit of concentration by evaporation under the exhausted receiver.

Sulphovinate of Baryta 2071. *Sulphovinate of Baryta* was obtained by Gay-Lussac, in rhomboidal prisms terminated by a rhomboidal pyramid; the crystals were transparent, and permanent, but easily decomposed by heat.

2072. A strong analogy appears to subsist between the hyposulphuric and sulphovinous acids; and it will probably be found that the latter derives its peculiarities from the combination of a portion of ethereal oil.[‡]

2073. When ether is passed over red-hot platinum wire, or Pl. 2. consumed in the lamp without flame, fig. 34, (181,) a peculiar acid substance is produced, which has been subjected to an interesting series of experiments, by Mr J. F. Daniell.[§] He obtained it by placing the lamp, filled with ether, and properly trimmed with a coil of glowing platinum wire, under the head of an alembic, in which the vapour was condensed, and collected in a phial applied to its beak.

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[*] Brande's *Pharmacy*, 453.

[†] Thomson's *Annals*, xiv. 44.

[‡] Annales de Chimie, xiii. Quarterly Journal of Science and the Arts, ix. 397.

[§] Quarterly Journal of Science and Arts, vi. 318.

Lampic acid.

Lampic acid, for so Mr Daniell has termed this product, is colourless, sour, and pungent; its vapour is very irritating, and its specific gravity, when purified by carefully driving off a portion of alcohol which it contains, is about 1,015. It reddens vegetable blues, and decomposes the alkaline carbonates with effervescence.

Mr Daniell has described many of the combinations of this acid, which he terms *lampates*, and has given some experiments upon its composition, whence he deduces its ultimate components, as follow :

Composition.

1 proportional carbon	6
1 ——— hydrogen . . .	1
1 ——— water	9
	16

When lampic acid is added to the solutions of silver, gold, platinum, mercury, and copper, and the mixture heated, the metals are thrown down in the metallic state.

On distilling the *lampate of mercury*, made by digesting the peroxide of mercury in the acid, Mr Daniell obtained the concentrated or pure lampic acid, in the form of a very dense liquid with an intensely suffocating odour.

b. NITRIC ETHER.

2074. When strong nitric acid and alcohol are mixed in equal proportions, a violent action presently ensues; there is a very copious evolution of an inflammable aëriform body, which has been called *nitrous etherized gas*, and which appears to be a compound of nitrous ether, and nitric oxide. If we endeavour to condense the volatile products, we find that the receiver contains alcohol, water, nitrous ether, nitrous acid, and acetic acid; and that the greater portion of the true ether has made its escape with the gaseous products. Thenard has paid much attention to this subject, and has given the following process for obtaining nitric ether.*

Preparation.

Introduce into a sufficiently capacious retort equal weights of alcohol, (specific gravity 820) and of nitric acid of commerce (specific gravity 1,30) and connect it with five Woulfe's bottles, the first of which is empty, and the remaining four half filled with a saturated solution of salt in water. Apply a gentle heat to the retort, till the liquor begins to effervesce; then withdraw the fire, and the gaseous matter passing through the bottles, which should be kept cold by ice, deposits the ether upon the saline solution, from which it is to be decanted, shaken with chalk, and re-distilled at a very gentle heat.†

Properties

2075. Nitric ether, thus prepared, has the following properties: It has a very powerful ethereal odour; its colour is pale yellow; its taste very pungent; its specific gravity above that of alcohol, but less than that of water. It is more volatile than sulphuric ether, and the heat of the hand is sufficient to produce its ebullition. It is soluble in 48 parts of water; and in all proportions in alcohol; this last solution is the *spiritus etheris nitrosi*, or *sweet spirit of nitre of the Pharmacopœia*. It is decomposed by keeping, and nitric and acetic acids are formed in it. According to Thenard, nitric ether consists of

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* Mém. d'Arcueil, Tom. i, and Traité de Chim. iii.

† See description of an apparatus for this process, by Dr Hare in *Am. Jour.* vol. ii. p. 326.

Oxygen	48,52
Carbon	28,45
Nitrogen	14,49
Hydrogen	8,54
	100,00

Composition.

Dr Thomson[*] concludes, from analogy, that nitric ether consists of 4 proportionals of olefiant gas, = 28, and 1 of nitric acid, = 54; or, of

4	proportionals of hydrogen	1 × 4 =	4
4	——— carbon	6 × 4 =	24
1	——— nitrogen	. . . .	14
5	——— oxygen	8 × 5 =	40
			82

2076. When nitric acid, holding mercury or silver in solution, is added to alcohol, a white precipitate is formed during the effervescence that ensues, which is possessed of powerful detonating properties. (1537 & 1588).

c. MURIATIC ETHER.

Preparation.

2077. Muriatic ether was thus obtained by Thenard[†]: Equal measures of strong liquid muriatic acid, and highly rectified alcohol, are put into a retort communicating with a receiver, from which a tube passes into a Woulfe's bottle containing warm water, and having a tube of safety: from this there issues a bent tube passing into a bottle surrounded by ice. On applying heat to the retort, a portion of alcohol and acid pass into the first receiver, and the ether in a gaseous state escapes through the warm water and the bent tube, and is condensed in the cold vessel.

Properties.

2078. At a temperature somewhat below 70° muriatic ether passes into the state of vapour, of which the specific gravity is about 2,220, that of air being 1,000; it is highly inflammable, its taste sweetish and ethereal, and it is soluble in its own bulk of water at 64°. Its specific gravity in a liquid state, at 40°, is ,870. It is remarkable that this ether does not affect vegetable blues, nor does it afford traces of chlorine to the usual tests; but, when burned, muriatic acid is immediately perceptible.

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[*] System, vol. ii. p. 341.

[†] Memoires d'Arcueil, Tom. i.

2079. According to Thenard, this ether, contains

Composition.

Muriatic acid	29,44
Carbon	36,61
Oxygen	23,31
Hydrogen	10,64
	100,00

Dr Thomson considers muriatic ether as a compound of four proportionals of olefiant gas, and one of muriatic acid ; hence it would contain

5 proportionals of	hydrogen	1 × 5 =	5,
4 ————	carbon	6 × 4 =	24,
1 ————	chlorine	. . . .	36
			65

d. Hydriodic Ether.

2080. By distilling two measures of alcohol, with one of concentrated liquid hydriodic acid, Gay-Lussac obtained an ethereal liquid, of a specific gravity of 1,920 at 72°, and requiring a temperature of 148° for its ebullition. Its properties have not been very satisfactorily investigated, nor have any accurate experiments demonstrated its composition.*

Acetous Fermentation.

2081. When any of the vinous liquors are exposed to the free access of atmospheric air at a temperature of 80° or 85°, they undergo a second fermentation, terminating in the production of a sour liquid, called *vinegar.* During this process a portion of the oxygen of the air is converted into carbonic acid; hence, unlike vinous fermentation, the contact of the atmosphere is necessary, and the most obvious phænomenon is the removal of carbon from the beer or wine. Vinegar is usually obtained from malt liquor or cider, while wine is employed as its source in those countries where the grape is abundantly cultivated. Vinegar.

2082. The colour of vinegar varies according to the materials from which it has been obtained ; that manufactured in England is generally artificially coloured with burnt sugar : its taste and smell are agreeably acid. Its specific gravity is liable to much variation ; it seldom exceeds 1,0250. When exposed to the air it becomes mouldy and putrid, chiefly in consequence of the mucilage which it contains, and from which it may be in some measure purified by careful distillation. According to Mr. R. Phillips,† when good malt vinegar of the specific gravity of 1,020 is distilled, the first eighth that passes over is of the specific gravity 0,997 ; the next six-eighths are of specific gravity 1,0023, and a fluid ounce decomposes 8,12 grains of precipitated carbonate of lime. The lightness of the first por- Properties.

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* Annales de Chimie, xci.

† Remarks on the London Pharmacopœia.

tion is owing to its containing alcohol, consequently, in the *Pharmacopœia* process it is ordered to be rejected. The term *distilled vinegar*, or *dilute acetic acid*, is properly applied to the second portion; it is erroneously called *acetic acid*, in the *London Pharmacopœia*. The matter which remains in the still is empyreumatic, and generally contains some other vegetable acids: when the vinegar has been adulterated, which is not unfrequently the case, we sometimes find in it muriatic and sulphuric acids.

Acetic acid.

2083. Distilled vinegar is colourless, and of a flat acid taste; it consists essentially of the real acid diluted with water. To obtain *acetic* acid, or, as it has been sometimes called, *radical vinegar*, distilled vinegar may be saturated with some metallic oxide, and the acetate thus obtained, subsequently decomposed.

2084. Acetic acid is thus procured by distilling *acetate of copper*, or *crystallized verdigris*, in a glass retort heated gradually to redness: it requires re-distillation to free it from a little oxide of copper which passes over in the first instance. Acetic acid may also be obtained by distilling *acetate of soda* or *acetate of lead* with half its weight of sulphuric acid: or from a mixture of equal parts of sulphate of copper and acetate of lead; in these cases, the acid passes over at a moderate temperature.

Pyroligneous acid.

2085. A considerable quantity of acetic acid is also now procured by the distillation of wood in the process of preparing charcoal for the manufacture of gunpowder. The liquor at first procured is usually termed *pyroligneous acid;* it is empyreumatic and impure, and several processes have been contrived to free it from tar and other matters which it contains. It may be saturated with chalk and evaporated, by which an impure acetate (pyrolignate) of lime will be obtained, and which, mixed with sulphate of soda, furnishes, by double decomposition, sulphate of lime and acetate of soda: the latter distilled with sulphuric acid affords a sufficiently pure acetic acid, which by dilution with water may be reduced to any required strength. The purification of this acid has been brought to great perfection by Dr Bollman.

Apparatus for preparing.

2086. The apparatus used in the preparation of this acid is represented by fig. 131; *a* is a section of the cylinder in which the wood, deprived of its bark, is placed; *b* a different section, *c* the elevation of the furnace, *d* the outer stopper, *e* an inner shutter which is smeared round its edge with clay-lute, and secured to the mouth of the cylinder, *f* the pipe for conveying off the acid into the casks *g*, which are connected by the tubes *h*, *i* is the pipe for conveying the tar into the receiver *k*. The escape of the elastic fluids is provided for by bent tubes inserted in the casks, and terminating under the surface of water. The average quantity of impure acid obtained from each cwt. of wood is about four gallons and a half. The crude acid is rectified by a second distillation in a copper still.*

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* See Parkes's Essays, i. 398.

Properties.

2087. Acetic acid obtained by these processes is transparent and colourless, its odour highly pungent and it blisters and excoriates when applied to the skin. Its specific gravity is 1,080. It is extremely volatile, and its vapour readily burns. It combines in all proportions with water, and when considerably diluted, resembles distilled vinegar. When highly concentrated, it crystallizes at the temperature of 40°, but liquefies when its heat is a little above that point.

The most probable constitution of acetic acid, derived from the analysis of its salts, is the following:

Composition.

	Atoms.		
Carbon	4	24	48
Oxygen	3	24	48
Hydrogen	2	2	4
		50	100

Its equivalent, according to this view of its composition is 50. H. 2. 347.

Acetates.

2088. The acetates are all soluble in water, and mostly very soluble: many of them are deliquescent, and difficultly crystallizable; they are decomposed by sulphuric acid, and when submitted to destructive distillation, furnish a modified vinegar, which has been termed *pyroacetic acid* or *spirit*: these decompositions have been fully investigated, and the properties of the pyroacetic spirit inquired into, by Mr Chenevix.*

The following are among the most important of the acetates:

— of ammonia.

2089. *Acetate of Ammonia* is a very deliquescent, soluble salt, and extremely difficultly crystallizable. In solution, obtained by saturating distilled vinegar with carbonate of ammonia, it constitutes the *ammoniæ acetas liquidus* of the *U. S. P.* which has long been used in medicine as a diaphoretic, under the name of *spirit of Mindererus.*

— of potassa.

2090. *Acetate of Potassa* is usually formed by saturating distilled vinegar with carbonate of potassa, and evaporating to dryness. If this salt be carefully fused, it concretes into a lamellar deliquescent mass on cooling. It is the *terra foliata tartari*, and *febrifuge salt of Sylvius* of old pharmacy. It dissolves in its own weight of water at 60°, and the solution has an acrid saline taste. It consists of one proportional of each of its components.

— of soda.

2091. *Acetate of Soda* forms prismatic crystals, not deliquescent, of an acrid bitterish taste, and soluble in rather less than three parts of water at 60°. It is the *terra foliata crystallisata* of old writers. It consists of 32, soda + 50 acetic acid.

— of lime.

2092. *Acetate of Lime*, is a difficultly crystallizable salt, readily soluble in water, and of a bitter saline taste; consisting of 28 lime + 50 acid. It is sometimes obtained by saturating the vinegar formed during the distillation of wood, and employed in the preparation of *acetate of alumina*, which is used by the calico-printers as a mordant.

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* Annales de Chimie, xlix.

Acetate of Baryta. 2093. *Acetate of Baryta* furnishes aicular crystals of a sour and bitterish taste: in cold weather the concentrated solution congeals into a silky congeries of crystals. It requires rather more than its own weight of water at 60° for solution, and consists of 50, acid + 78, baryta.*

— of Iron. 2094. *Acetate of Iron.* The acetic acid combines with both oxides of iron. The *protacetate* is formed by digesting sulphuret of iron in acetic acid; it yields green prismatic crystals, of a styptic taste, and readily soluble in water; the solution becomes brown by exposure to air, and passes into *peracetate*, which is uncrystallizable, and obtained by digesting iron in acetic acid. This compound is extensively used by calico-printers, who prepare it either by digesting iron in pyroligneous acid, or by mixing solution of acetate of lead with sulphate of iron, and exposing the filtered solution to air.

— of Zinc. 2095. *Acetate of Zinc*, is formed either by dissolving oxide of zinc in acetic acid, or by mixing a solution of sulphate of zinc with one of acetate of lead. It crystallizes in thin shining plates of a bitter and metallic taste, very soluble, but not deliquescent. This salt is sometimes used in pharmacy, chiefly as an external application. According to Messrs Aikin, the specific gravity of a saturated solution of acetate of zinc, made by digesting the salt in distilled vinegar, is 1055. Of this solution 900 grains contain 53 of dry, or 82,6 of crystallized acetate. One ounce by measure of the solution weighs 506 grains, and contains 29,8 grains of dry, or 46,5 grains of crystallized salt.

— of Tin. 2096. *Acetate of Tin.* This metal is slowly acted on by acetic acid, but a *protacetate* and *peracetate of tin* may be made by mixing acetate of lead with saturated solutions of the protomuriate and permuriate of tin. These solutions have been recommended as mordants for the use of dyers. The protacetate is crystallizable. Vinegar kept in tin vessels dissolves a very minute portion of the metal; and in pewter vessels it likewise dissolves a small portion of the lead, where in contact both with the vinegar and air; hence distilled vinegar, which has been condensed in a pewter worm, affords generally traces of both metals.†

— of Copper. 2097 *Acetate of Copper.* By exposing copper to the fumes of vinegar, it becomes gradually incrusted with a green powder called *verdigris*,* which is separable by the action of water, into an insoluble *subacetate of copper*, and a soluble *acetate*.

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* *Acetate of Strontia* furnishes small permanent crystals, consisting of 50 acid + 55 strontia. *Acetate of Magnesia* is uncrystallizable, and of a bitterish sweet taste. It consists of 50 acid + 30 magnesia. *Acetate of Manganese*, formed by dissolving the protocarbonate in acetic acid, crystallizes in rhomboidal tables, permanent, and of a reddish colour and astringent metallic taste, soluble in 3½ parts of water at 60°. They consist of 70 acid and water + 30 protoxide of manganese.—John, Gehlen's *Journal*, iv.

† Vauquelin, *Annales de Chimie*, xxxii.

Acetate of copper may be obtained by digesting verdigris, or oxide of copper, in acetic acid; by evaporating this solution, it is obtained in prismatic crystals of a fine green tint. It dissolves sparingly in water and alcohol, and communicates a beautiful blue-green colour to the flame of the latter; by distillation it affords a very pure acetic acid.

Acetate of Lead.

2098. *Acetate of Lead*, is the *Sugar of Lead*, and *Salt of Saturn* of the old chemists: it may be regarded as the most important of the acetates; it is used in pharmacy, and by dyers and calico-printers for the preparation of acetate of alumina and of iron, which are formed by mixing its solution with that of the sulphates of those metals, an insoluble sulphate of lead being at the same time produced. Acetate of lead is formed by digesting the carbonate in distilled vinegar, or in the acetic acid obtained by the destructive distillation of wood; it usually occurs in masses composed of acicular crystals; but by careful crystallization it may be obtained in quadrangular prisms. Its taste is sweet and astringent, and it is soluble in about four parts of water at 60°. It is sometimes improperly termed a *superacetate*, but the salt is neutral, though when dissolved in water containing the smallest portion of carbonic acid, a white insoluble compound of lead falls, and a little acetic acid being liberated, the solution is rendered sour.

Carbonic acid passed through a solution of acetate of lead, precipitates, according to Mr James South, exactly half the quantity of the oxide which the salt contains; hence a *binacetate* is probably formed which however does not afford crystals.

Composition.

According to the experiments of Berzelius, acetate of lead consists of

Acetic acid	26,45
Protoxide of lead	59.25
Water	14,30
	100

hence the dry acetate is composed of

1 proportional of acetic acid	50,
1 ——————— yellow oxide of lead	112,
	162

When acetate of lead is submitted to destructive distillation it furnishes a considerable quantity of a peculiar fluid, smelling and burning like alcohol.†—PROUST, *Journal de Physique*, Tom. lvi.

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* *Diacetate*, T.—For a description and analysis of the acetates of copper see Thomson's *First Principles*, ii. 383.

† Dr Thomson has described several acetates of lead, for an account of which see *First Principles*, vol. ii.

Goulard's extract.

2099. When 100 parts of sugar of lead are boiled in water with about 150 of yellow oxide, or of finely powdered litharge, a salt is obtained which crystallizes in plates, and is less sweet and soluble than the acetate; it has been termed ***subacetate of lead***, and consists according to Berzelius of 1 proportional of acid = 50 + 3 proportionals of oxide of lead 336. This compound has long been used in pharmacy, under the name of *Goulard's extract of lead*. It is very rapidly precipitated by carbonic acid, of which it is a most delicate test; it also has a strong attraction for vegetable colouring matter, upon which principle Mr Brande employed it in his analysis of wines.*—*Phil. Trans.* 1813.

Acetate of Mercury.

2100. *Acetate of Mercury*. *Protacetate of Mercury* is most readily formed by mixing a solution of protonitrate of mercury with acetate of potassa. For this purpose dissolve three ounces of mercury in about four ounces and a half of cold nitric acid, and mix this solution with three ounces of acetate of potassa previously dissolved in eight pints of boiling water, and set the whole aside to crystallize, which takes place as the liquor cools, and the acetate of mercury then separates in the form of micaceous crystalline plates, which are to be washed in cold water, and dried on blotting paper.† In preparing this salt, the quantity of water for dissolving the acetate need not be so large as above directed, one pint being sufficient, but it is necessary, to pour the mercurial solution into the acetate. This salt has an acrid taste, and is very difficultly soluble in water, requiring according to Braconnot,‡ 600 parts of water. It is insoluble in alcohol. It was one used in medicine.§

Of alumina.

2101. *Acetate of Alumina*. This salt is extensively employed by calico-printers as a mordant or basis for fixing colours; they produce it by mixing solutions of alum and acetate of lead: about three pounds of alum are dissolved in eight gallons of water and a pound and a half of sugar of lead stirred into it; a copious formation of sulphate of lead ensues which is allowed to subside, and the clean liquor holding acetate of alumina and a portion of undecomposed alum in solution, is then drawn off, a portion of pearlash and chalk being added to it previous to use, in order to saturate any excess of acid.

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* *Acetate of Antimony*, formed by digesting the protoxide in acetic acid was once employed as an emetic. *Acetate of Bismuth* may be formed by adding nitrate of bismuth to a concentrated solution of acetate of potassa; a precipitate falls, which re-dissolves on the application of heat, and afterwards affords scaly crystals. The addition of acetic acid to nitrate of bismuth prevents its precipitation when diluted. (1)*Acetate of Cobalt* may be obtained by digesting oxide of cobalt in acetic acid; it is uncrystallizable, and furnishes a sympathetic ink, colourless when cold, but blue when heated. *Acetate of Uranium* forms four-sided prismatic crystals of a yellow colour. *Acetate of Titanium*, not examined. *Acetate of Cerium*. Recently precipitated oxide of cerium readily dissolves in acetic acid, and yields small crystals on evaporation, of a sweetish taste, permanent, and readily soluble in water. (2)*Acetate of Nickel* forms green rhomboidal crystals.

(1) Morveau, *Encycl. Method. Chimie*, 1. 10.

(2) Hisinger and Berzelius, Gehlen's *Journal*, ii. 414.

† Edinburgh Pharmacopœia.

‡ Annales de Chimie, lxxxvi. 92.

§ *Peracetate of Mercury* is formed by digesting the peroxide in acetic acid; it does not crystallize, and affords on evaporation a deliquescent yellow mass, which is decomposed by water into a *superperacetate*, which remains dissolved, and an insoluble *subperacetate*. (*a*) *Acetate of Silver* is obtained by boiling the acid on oxide of silver, or by mixing solutions of acetate of potassa and nitrate of silver: it forms acicular crystals of an acrid metallic taste.

a Proust, *Journal de Phys.* lvi.

Acetate of alumina, formed by digesting recently precipitated alumina in acetic acid, may be procured in deliquescent acicular crystals of an astringent taste, and containing, according to Richter, 73,81 acid + 26,19 alumina: hence it is probably a *binacetate*.

2102. When acetic acid and alcohol are repeatedly distilled together, a portion of *acetic ether* is formed, which has a peculiar and agreeable taste and smell, and a specific gravity of about ,860 at 60°. It boils at about 160°, is highly inflammable, and emits acetic acid among its products of combustion. This ether is directed in some of the foreign Pharmacopœiæ for medical use, and the following is perhaps the best process for its production. Introduce into a tubulated retort 3 parts of acetate of potassa, 3 of alcohol, and 2 of sulphuric acid, and distil to dryness. To the product add one-fifth its weight of sulphuric acid, and draw off by a gentle heat a quantity of ether equal to that of the alcohol originally employed. Acetic ether.

Acetic ether is much more soluble in water than sulphuric ether: according to M. Thenard, water at 60° dissolves about a 7,5 part of its weight, and the solution is permanent. Caustic potassa decomposes it, and forms acetate of potassa.

Oxalic, citric, tartaric, and benzoic acids have been employed in the formation of ethers; the presence of a mineral acid is indispensable to their formation.*

CHAPTER VIII.

OF ANIMAL SUBSTANCES.

2103. The different sections of this chapter will contain an account of the ultimate and proximate principles of the substances belonging to the animal creation, of the different methods of analysis by which these principles are obtained, and of such of the animal functions as are concerned in their production, where these are susceptible of chemical elucidation.

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* Ure's *Dictionary*, Art. *Ether*.

SECTION I. *Of the ultimate Principles of Animal Matter, and of the products of its destructive Distillation.*

2104. The proximate principles of the animal creation consist, like those of vegetables, of a few elementary substances, which by combination in various proportions, give rise to their numerous varieties. Nitrogen. Carbon, hydrogen, oxygen, and nitrogen, are the principal ultimate elements of animal matter; and phosphorus and sulphur are also often contained in it. The presence of nitrogen constitutes the most striking peculiarity of animal, compared with vegetable bodies; but as some vegetables contain nitrogen so there are also certain animal principles, into the composition of which it does not enter.

2105. The presence of nitrogen stamps a peculiarity upon the products obtained by the destructive distillation of animal matter, and which are characterized by the presence of ammonia, Ammonia. formed by the union of the hydrogen with the nitrogen. It is sometimes so abundantly generated as to be the leading product; thus, when horn, hoofs, or bones, are distilled *per se*, a quantity of solid carbonate of ammonia, and of the same substance combined with empyreumatic oil, and dissolved in water, are obtained; hence the pharmaceutical preparations called *spirit* and *salt of hartshorn*, and Dippel's *animal oil.* Occasionally the acetic, benzoic, and some other acids are formed by the operation of heat on animal bodies, and these are found united to the ammonia; cyanogen and hydrocyanic acid also frequently occur.

If the gas evolved during the decomposition of animal bodies be examined, it is generally inflammable, and consists of carburetted hydrogen, Carburetted hydrogen. often with a little sulphuretted and phosphuretted hydrogen; carbonic oxide, carbonic acid, and nitrogen, are also sometimes detected in it.

The coal remaining in the retort is commonly very difficult of incineration, a circumstance depending upon the common salt and phosphate of lime, which it usually contains, forming a glaze upon its surface which defends the carbon from the action of the air. Animal charcoal is also found to be more effectual in destroying colour and smell, than that obtained from vegetables.

Putrefaction. 2106. By the term *putrefaction* we mean the changes which dead animal matter undergoes, and by which it is slowly resolved into new products. These changes require a due temperature, and the presence of moisture; for below the freezing point of water, or when perfectly dry, it undergoes no alteration.

During putrefaction the parts become soft and flabby, they change in colour, exhale a nauseous and disgusting odour, diminish considerably in weight, and afford several new products, some of which escape in a gaseous form, others run off in a liquid state, and others are contained in the fatty, or earthy residuum.

Antiseptics.

The presence of air, though not necessary to putrefaction, materially accelerates it, and those gases which contain no oxygen, are very efficient in checking or altogether preventing the process. Carbonic acid also remarkably retards putrefaction; and if boiled meat be carefully confined in vessels containing that gas, it remains for a very long time unchanged, as seen in M. Appert's method of preserving meat.

There are several substances which, by forming new combinations with animal matter, retard or prevent putrefaction, such as many of the saline and metallic compounds; sugar, alcohol, volatile oils, acetic acid, and many other vegetable substances also stand in the list of anti-putrefactives, though their mode of operating is by no means understood.

Effect of the effluvia.

Fumigation.

2107. The effluvia which arise from putrescent substances, and more especially those generated in certain putrid disorders, have a tendency to create peculiar diseases, or to give the living body a tendency to produce poisons analogous to themselves. An atmosphere thus tainted by infectious matter, may be rendered harmless by fumigation with the volatile acids, more especially the nitrous and the muriatic; chlorine is also very effectual: the vapour of vinegar, though sometimes useful in covering a bad smell, is not to be relied on. It appears evident that the acid and chlorine act chemically upon the pernicious matter, and resolve it into innocuous principles.

Adipocere.

2108. When muscular flesh is immersed in a stream of running water, it is partially converted into a substance having many of the properties of fat combined with a portion of ammonia. The same changes have been observed where large masses of putrefying animal matter have been heaped together, or where water has had occasional access to it. Nitrate of ammonia is also sometimes formed under the same circumstances.

2109. Instead of considering the proximate principles of animals under separate sections, as has been done in regard to vegetable bodies they may be made known under the heads of those substances in which they occur, the principal of which are the following:

1. Blood. Albumen. Colouring Matter.
2. Milk. Sugar of Milk.
3. Bile. Resin of Bile.
4. Lymph. Mucus. Synovia, Pus, &c.
5. Urine. Urea. Urinary Calculi.
6. Skin. Membrane.
7. Muscle. Ligament. Horn. Hair.
8. Fat. Spermaceti, &c.
9. Cerebral substance.
10. Shell and Bone.

SECTION II. *Of the Blood.*

2110. IN the higher orders of animals the blood is of a red colour, florid in the arteries, and dingy in the veins. The specific gravity of human blood is liable to some variation. I have found it as low as 1,050 and as high as 1,070, but am unable to refer to any circumstances which might be considered as the cause of this difference. (BRANDE.)

Serum and crassamentum.

When blood is drawn from its vessels in the living animal, it soon concretes into a jelly-like mass, which afterwards gradually separates into a fluid *serum*, of a pale straw colour, and a coagulated *crassamentum* or *cruor*, which is red. The cause of this coagulation is quite unknown.

Properties of serum.

2111. The specific gravity of the serum of the blood, is upon an average 1,030. It reddens the yellow of turmeric, and changes the blue of violets to green, a property derived from a portion of soda. At a temperature of 160°, it becomes a firm yellowish white coagulum, resembling in appearance and properties the coagulated white of egg, and, as the principle to which this property is owing is the same in both substances, it has been called *albumen*. Alcohol, and many of the acids, also occasion the coagulation of the serum of blood.

100 parts of human serum contain between eight and nine parts of albumen, rather less than one part of carbonate of soda, and about the same quantity of common salt, the remaining 90 parts being water. These at least are the proportions which Mr Brande's experiments lead him to believe correct; but the analysis is involved in so much difficulty that he considers the results only as approximating to the truth; indeed it is probable that the composition of the serum is liable to much variation.*

Albumen.

2112. *Albumen*, which constitutes a leading ingredient in the serum, and which we shall presently find also in the cruor, is a very important animal principle, and is found in the greater number of animal fluids and solids.

Liquid Albumen is soluble in water, and always contains a notable portion of soda, indicated by its action on vegetable

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* Dr Marcet and Berzelius have each given an analysis of the serum of human blood; the following are their results.

Marcet.	
Water	900,
Albumen	86,8
Muriates of potassa and soda	6,6
Muco-extractive matter	4,0
Carbonate of soda	1,65
Sulphate of potassa	0,35
Earthy phosphates	0,60
	1000,00

Medico Chirurgical Transactions, Vol. ii.

Berzelius.	
Water	905,0
Albumen	80,0
Muriates of potassa and Soda	6,0
Lactate of soda, with animal matter	4,0
Soda and phosphate of soda with ditto	4,1
Loss	0,9
	1000,0

Annals of Philosophy, Vol. ii.

colours. It is coagulated by heat, acids, and alcohol, unless it be considerably diluted with water, in which case a portion separates in the form of white flakes after some hours' standing. Solution of corrosive sublimate, added to albumen, very much diluted, produces a cloudiness, and hence it is a useful test of albumen.* It is also instantly coagulated by Voltaic electricity; and if two platinum wires connected with a small battery be immersed into a diluted albumen, it will cause a very rapid coagulation at the negative pole, and scarcely any effect at the positive pole. This circumstance induced Mr Brande to attribute the coagulation to the removal of the alkali, by alcohol, and by acids; but how heat operates is not very obvious, unless we be allowed to consider it as effecting a kind of decomposition of the liquid albumen. We might thus consider liquid albumen as a compound of albumen and soda dissolved in water: the effect of heat would then be to transfer the soda to the water, and thus occasion a coagulation; and a solution of soda is always found oozing from coagulated serum, and has sometimes been called *serosity;* in time it re-acts upon the coagulum, and dissolves a portion of it.

Coagulated by Voltaic electricity.

2113. When albumen is dried in a moderate heat, it shrinks and becomes brown and semi-transparent, resembling horn in appearance and properties. In this state it scarcely dissolves in boiling water, though it gradually softens; it is not prone to decomposition; it dissolves in the alkalies, a portion of ammonia being evolved and a saponaceous compound formed. Dilute nitric acid converts it into a substance having the properties of gelatine.† Effect of heat.

By destructive distillation albumen furnishes a variety of products characterized by the presence of a large proportion of ammonia. According to Gay-Lussac and Thenard, (*Recherches Physico-chymiques*) its ultimate constituents are Products of its distillation.

Carbon	52,883
Oxygen	23,872
Hydrogen	7,540
Nitrogen	15,705
	100,000

2114. When the coagulum of the blood is carefully washed under a small stream of water, the colouring matter is gradually dissolved, and washed out of it, and a white fibrous substance remains, which has been termed *fibrina* or *coagulable lymph*, but of which the chemical properties are those of albumen. Fibrin.

It sometimes happens, when the blood is long in coagulating, as in certain inflammatory diseases, that a portion of this albumen is left without the colouring matter, forming what has been called the *buffy coat of blood;* in this case it is so tough as to admit of being removed from the coloured portion, and when dried, shrinks up, and appears exactly like horn. Buffy coat.

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* Bostock, Nicholson's *Journal*, xiv.

† Hatchett, *Phil. Trans.* 1800.

Although the cause of the spontaneous coagulation of blood be unknown, the process consists in a portion of the albumen separating in a solid form along with the colouring matter, while another portion remains dissolved in the serum; this effect is somewhat analogous to the crystallization of a saline solution, in which one portion of the salt separates, while another remains dissolved.

Colouring matter.

2115. The colour of the blood has generally been referred to small globules of a red colour, which by the aid of the microscope may be discerned in it; and it was supposed that these globules are soluble in water. But it has been shown by Dr Young, that this is not the case, and that the effect of water is to dissolve the colouring matter only, leaving the globule perfectly colourless; in this state the globular particles have the properties of albumen. The diameter of globules in human blood varies from $\frac{1}{6000}$ to $\frac{1}{4000}$ of an inch.*

The colouring matter of the blood can scarcely be obtained free from other substances. By stirring it during coagulation, a considerable portion is diffused through the serum from which it afterwards subsides. Vauquelin advises the digestion of the coagulum, drained of serum, in dilute sulphuric acid, at a temperature of 160°. The liquid, filtered while hot, is to be evaporated to half its bulk, and nearly saturated with ammonia; the colouring matter falls, and is to be washed and dried.† We must not, however, trust animal principles to these complex operations; and there can be little doubt that the colouring principle has undergone some change in M. Vauquelin's process.

A peculiar principle.

The chemical properties of the colouring matter of the blood show that it is a peculiar animal principle. It is soluble in cold water, and the solution, when boiled, deposits a brown sediment of altered colouring matter. Muriatic, dilute sulphuric, and several of the vegetable acids, and the caustic and carbonated alkalies, readily dissolve the colouring matter, and form solutions of different tints of red, and of a peculiar greenish hue when viewed by transmitted light. Nitric acid instantly renders these solutions brown, and decomposes the red principle. These experiments, of which a detailed account is given in the *Philosophical Transactions* for 1812, led Prof. Brande to regard the colouring matter of the blood as a distinct proximate principle of animal matter, perfectly independent of the presence of iron, to which its peculiarities were at one time referred by M. M. Fourcroy and Vauquelin; and the latter of these chemists has more lately verified Prof. Brande's conclusions in the above-quoted memoir. Berzelius, whose labours in animal chemistry are so extended and well known, has, however, obtained different results; he finds the crassamentum of the blood to consist of

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* Remarks on Blood and Pus, in Dr Young's *Medical Literature*.

† Ann. de Chim. et Phys. Tom. i.

Composition of the crassamentum.

Colouring matter	64
Fibrin and albumen	36
	100

The colouring matter, when incinerated, affords a residue, consisting of

Colouring matter.

Oxide of iron	50,0
Subphosphate of iron	7,5
Phosphate of lime with magnesia	6,0
Lime	20,0
Carbonic acid and loss	16,5
	100,0

The iron appears to be regarded by Berzelius as contributing to the red colour of the blood,* a conclusion which Prof. Brande's experiments, detailed in the paper already quoted, by no means warrant, and which is also at variance with the opinion of M. Vauquelin.

Blood contains carbonic acid.

2116. Besides the principles now enumerated, and which may be considered as essential to the blood, it often contains carbonic acid, which escapes when the blood is gently heated, or placed under the exhausted receiver of the air-pump.

Experiments on the blood, in different diseases, have thrown no light whatever on their nature, nor have any material differences been found in the blood of the same animal at different periods, or in that of different animals of the same class.

SECTION III. *Milk.*

2117. THE chemical properties of this secretion differ somewhat in different animals. The milk of the cow has been most attentively examined, and it has the following properties:

Properties.

It is nearly opaque; white, or slightly yellow; of an agreeable sweetish taste, and a peculiar smell. Its specific gravity varies from 1018 to 1020. It boils at a temperature a little above that of water, and freezes at 32°. When allowed to remain a few hours at rest, a thick unctuous liquid collects upon its surface called *cream;* the colour of the remaining milk becomes bluish white and when heated to about 100° with a little *rennet*, it readily separates into a *coagulum* or *curd*, and a *serum* or *whey*. In this way the three principal constituents of milk are separable from each other.

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* Thomson, *System*, vol. iv. p. 501.

2118. By the process of churning, cream is separated into *butter*, and *butter-milk*, the latter being the whey united to a portion of curd.*

Butter may be considered as an animal oil, containing a small portion of curd and whey. It liquefies at about 98°, and by this process the impurities are separated, and it remains a longer time without becoming rancid.

Curd.

2119. The *curd* of milk has the leading properties of coagulated albumen, and, like that principle, is coagulable by alcohol and acids, and is also similarly affected by Voltaic electricity; heat slowly produces the same effect, and by boiling milk, the albumen separates in successive films.

Cheese.

2120. Curd, in combination with various proportions of butter, constitutes the varieties of *cheese;* that containing the largest quantity of oil becomes semi-fluid when heated; it is prone to decomposition, and a large quantity of ammonia is then formed in it; whereas bad cheese, which consists of little else than curd or albumen, shrinks and dries when heated, curling up like a piece of horn.

Whey.

2121. *Whey* is a transparent fluid of a pale yellow colour and a sweetish flavour; by evaporation it affords a minute quantity of saline matter, and a considerable portion of sugar of milk.

Sugar of milk.

2122. *Sugar of Milk* may be obtained in white rhomboidal crystals, of a sweet taste, and soluble in seven parts of water at 60°, but insoluble in alcohol. When exposed to heat, it affords nearly the same products as common sugar. It consists, according to Berzelius, when deprived of water, of

Carbon	45,267
Oxygen	48,348
Hydrogen	6,385
	100,000

Action of nitric acid.

2123. When sugar of milk is treated with nitric acid, it affords a peculiar acid, similar to that above-mentioned, as obtained from gum (1785). To procure this acid, one part of powdered gum arabic may be digested in two of nitric acid, in a moderate heat; as soon as effervescence commences, set the flask in a cool place, and a quantity of white powder subsides, which is to be collected upon a filter, digested in dilute nitric acid to separate oxalate of lime, and subsequently purified by boiling water, which deposits the *mucic* or *saclactic acid* on cooling. If sugar of milk be used instead of gum, it is obtained pure by the first operation. This acid is not crystallizable, and is sparingly soluble in water, requiring 60 parts at 212°, and is deposited as the solution cools, in the form of a white gritty powder, of a slightly acid taste. It combines with

Mucic acid.

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* According to Berzelius, 100 parts of cream, of the specific gravity of 1024, consist of

Butter	4,5
Curd	3,5
Whey	92,0
	100,0

the metallic oxides, and forms a class of salts called *saccholates.* It consists, according to Berzelius,* of

Carbon	33,430
Oxygen	61,465
Hydrogen	5,105
	100,000

2124. The *saccholates*, or *saclactates*, have scarcely been examined. With ammonia, potassa, and soda, this acid forms crystallizable compounds, more soluble than the acid. The saclactates of lime, baryta, and strontia, are insoluble, as are those of silver, mercury, and lead. Saclactates.

2125. When milk or whey are exposed to a temperature between 60° and 80°, they undergo a spontaneous change, attended by the production of an acid, which was originally examined by Scheele, and has been termed *lactic acid.* Fourcroy and Vauquelin have shown reason to suspect its peculiar nature, and were led to regard it as identical with the acetic acid. Berzelius has more recently revived the opinion of Scheele, but Prof. Brande is induced from his own experiments to believe, that if it be not the acetic acid originally, it becomes so by combination with a base, and subsequent separation by sulphuric acid. Lactic acid.

2126. In some cases whey may be made to undergo vinous fermentation; and the Tartars, it is said, prepare a kind of wine from the whey of mare's milk, which they call *Koumiss.*† Koumiss.

SECTION IV. *Bile.*

2127. THIS secretion is formed in the liver, from venous blood. It is an unctuous liquid, of a yellowish green colour, and its specific gravity is between 1020 and 1030. Its taste is intensely bitter, and it readily putrefies, exhaling a most nauseous odour. Properties.

2128. When the bile of the ox is distilled, it affords about 90 *per cent.* of insipid water; the residuum is brown, bitter, and may be re-dissolved in water; it affords traces of uncombined alkali, which appears to be soda. The acids render bile turbid, and separate from it a substance which possesses many of the properties of albumen. It is likewise coagulated by alcohol, and upon filtering off the clear liquor and evaporating it, an inflammable fusible substance is obtained, of an intensely bitter flavour, combined with a portion of soda and common salt: this has been termed the *resin of bile*, and appears to be the principle which confers upon it its chief peculiarities. We should, therefore, conclude, as the result of these observations, that bile consists of water, albumen, soda, a bitter resin, and some minute portions of saline matter. Resin of bile.

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* Annals of Philosophy, vol. v.

† Edinburgh Phil. Trans. vol. ii.

2129. Thenard separated from bile a peculiar substance, which he has termed *picromel;* but the process by which he obtained it is so complex, that it is doubtful whether it be a product or an educt.

Picromel.

2130. *Biliary Calculi* are of two kinds; those which most commonly occur, are soft, fusible, and of a crystalline texture, and inflammable. They have generally been considered as closely resembling spermaceti; they are soluble in boiling alcohol, in ether, and difficultly in oil of turpentine. Chevreul, having remarked some peculiarities in this substance, is induced to regard it as a peculiar animal principle, and distinguishes it by the name of *cholesterine.*

Biliary calculi.

Cholesterine.

2131. Cholesterine is fusible at 280°, and on cooling concretes into a crystalline mass; rapidly heated to about 400° it evaporates in dense smoke; it is insoluble in water, and nearly so in cold alcohol; boiling alcohol dissolves about $\frac{1}{20}$ its weight. It is soluble in nitric acid; but not convertible into soap by the alkalies.

2132. The other kind of biliary calculus resembles inspissated bile in appearance, but differs from it in being insoluble in alcohol and water. It is often mixed with variable proportions of the former, constituting biliary calculi of intermediate characters.

2133. The gall-stone of the ox is nearly insoluble in water and alcohol, and appears to consist chiefly of the yellow matter of bile; painters sometimes use it as a yellow pigment.

SECTION V. *Lymph, Mucus, Pus, &c.*

2134. THE liquid which lubricates the different cavities of the body, which is contained in the lymphatics, and which occasionally forms the chief contents of the thoracic duct, has been termed *lymph.* It is colourless, transparent, miscible in all proportions with water, does not affect vegetable blues, is not coagulated by acids or alcohol, but only rendered slightly turbid by the latter. It has the characters of a very weak solution of albumen.

Lymph.

The fluid which collects in cases of dropsy and in vesications is of a similar nature, but the proportion of albumen is liable to variation, and hence it is differently influenced by tests; when very rapidly thrown out from inflamed surfaces, it sometimes furnishes a coagulum, apparently as abundant as that of the serum of the blood.

Mucus.

2135. The term *mucus* has sometimes been applied to these fluids when they have undergone a certain degree of inspissation; at other times, it has been used to designate a very alkaline albuminous fluid. Dr Bostock has pointed out some circumstances in which mucus differs from liquid albumen, and has proposed subacetate of lead as a test for its presence.[*] But that salt is so easily decomposed by many vegetable and animal substances, as to render it of doubtful efficacy for this purpose.

Saliva.

2136. *Saliva* consists, according to Dr Bostock,[†] of

Water	80
Coagulated albumen	8
Mucus	11
Saline substances	1
	100

Prof. Brande found that it was copiously coagulable by the action of Voltaic electricity, and was hence induced to consider the mucus as a peculiar albuminous combination, not coagulable by the usual means.[‡]

Pancreatic juice.

2137. The *Pancreatic juice* has not been minutely examined, but from the experiments of Dr Fordyce, it would appear to differ little from saliva.

Tears.

2138. *Tears* contain a small portion of albumen combined with soda, muriate of soda, and water. There are also small portions of other salts.

Humours of the Eye.

2139. *The humours of the eye.* The *aqueous humour* is composed of water holding a minute quantity of albumen and saline matter in solution; the *crystalline lens* also contains more than half its weight of water, the remainder being an albuminous substance with traces of muriates.

Synovia.

2140. *Synovia* is the fluid which lubricates the surfaces of joints. It contains, according to Mr Hatchett,[§] a small portion of phosphate of lime, and of phosphate of soda and ammonia; the animal principle appeared to be albumen.

Pus.

2141. *Pus* is a term applied to a variety of secretions from abscesses and ulcerated surfaces. When it indicates a healing sore, it has been called *healthy pus*, and has the following properties. It has the consistency of cream, a yellowish colour, and exhibits, under the microscope, the appearance of globules diffused through a fluid.[||] Its specific gravity is about 1,030. It does not affect vegetable colours till it has been some time exposed to air, when it becomes slightly sour; it does not easily mix with water, alcohol, or dilute acids.[¶]

Formic acid.

2142. *Formic acid,* or acid of ants. This is a peculiar acid which exists in the red ant; it was examined by Fourcroy and Vauquelin who inferred that it is merely a mixture of acetic and malic acids. Dobereiner has formed it artificially, by slightly heating bi-tartrate of potassa or tartaric acid with black oxide of manganese. A great quantity of carbonic acid escapes, and a sour colourless liquid distils, which is formic acid. It may be obtained from red ants by infusing them in warm water and distillation. It is regarded as a secretion and as constituted of

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[*] Nicholson's *Journal*, vol. ix.

[†] Nicholson's *Journal*, vol. xiv.

[‡] Phil. Trans. 1809.

[§] Phil. Trans. 1799.

[||] Home, *On Ulcers*, 2 Edit. p. 13.

[¶] See Dr Pearson's *Experiments on Pus*, Nicholson's *Journal*, xxi.

	Atoms.	
Carbon	2	12
Oxygen	3	24
Hydrogen	1	1
		37

Or as constituted of 1 volume of the vapour of water + 2 volumes of carbonic oxide gas.* Its compounds are termed *Formiates.*

Castorine.

2143. *Castorine* is a new animal principle which was discovered by M. Bizio in Castor, and is prepared by boiling castor in 6 times its weight of alcohol; the filtered liquor is set aside for two or three days, when castorine is deposited in irregular masses. It is very sparingly soluble in water, more so in alcohol, and its solution in the latter affords prismatic crystals of a white colour. It burns with a brilliant light, and appears to consist of carbon, hydrogen and oxygen alone.

SECTION VI. *Urine, Urinary Calculi, &c.*

Urine.

2144. THIS secretion presents, perhaps, greater difficulties to the analytical chemist, than any other animal product; it is extremely complex, and subject to constant change in the proportions of its components, and in disease several new substances make their appearance.

The chemical history of the urine is of the utmost importance to the medical practitioner; it teaches the nature of the substances which occasionally predominate, so as to constitute *gravel* and *calculi;* and shows the means of influencing and modifying its composition.

The general characters of the urine are too well known to need description. Its specific gravity is of course liable to much variation even in the healthy state, fluctuating between 1005 and 1040. The average is about 1020.

Substances found in it.

2145. The substances that are always found in urine are, according to Prof. Brande's experiments, the following:

1. Water.
2. Carbonic acid.
3. Phosphoric acid.
4. Uric acid.
5. Phosphate of lime.
6. Phosphate of ammonia.
7. Phosphate of soda.
8. Phosphate of magnesia.
9. Common salt.
10. Sulphate of soda.
11. Albumen.
12. Urea.

2146. The existence of free acid in recently voided urine is easily demonstrated by its property of reddening vegetable blues, and it performs the important office of retaining some difficultly soluble salts in permanent solution; so that whenever this natural acidity is diminished, the urine has a tendency to deposit the earthy phosphates.

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* Ann. of Philos. N. S. ix. 390.

2147. The presence of ***carbonic acid*** may be shown by placing urine under the receiver of the air-pump; during exhaustion it escapes, sometimes copiously, but at other times in minute quantities only. Carbonic acid.

2148. The free ***Phosphoric acid*** may be shown by the addition of carbonate of lime, a portion of which is converted into phosphate of lime. Phosphoric acid.

2149. *Uric acid* is one of the peculiar characteristics of the urine; its presence may be shown by evaporating urine to half its bulk, which produces a precipitate consisting of phosphate of lime and uric acid; the former may be dissolved by dilute muriatic acid, which leaves the latter in the form of a reddish powder. This acid has been very ably examined by Dr Henry, who made it the subject of a thesis published in 1807: Dr Prout has also given much valuable information in relation to it. Uric acid.

Uric acid, called sometimes lithic acid, as constituting the principal ingredient in certain urinary calculi, may be abundantly obtained by digesting such calculi (2163) in caustic potassa, filtering the solution, and adding excess of muriatic acid, which causes a precipitate of uric acid, which is to be washed with warm water, and dried. How obtained.

Uric acid, thus obtained, is a grey powder, of scarcely any taste, and requiring according to Dr Henry 1720 parts of water at 60°, and 1150 parts at 212° for solution. It reddens infusion of litmus, and readily dissolves in caustic potassa, and soda; it is sparingly soluble in ammonia, and insoluble in the alkaline carbonates. Properties.

According to Dr Prout, uric acid requires at least 10000 parts of water at 60° for its solution, but urate of ammonia requires only about 480 times its weight at the same temperature, and affords a precipitate of uric acid, on the addition of any other acid; for these, among other reasons, Dr Prout regards urate of ammonia, and not pure uric acid, as existing in urine.

2150. Uric acid dissolves in nitric acid, and upon evaporation a residuum of a fine red tint is obtained, which is peculiar to this combination, and which Dr Prout has lately shown to possess distinct acid properties; he has called it *purpuric acid.*[*] Purpuric acid.

2151. When uric acid is submitted to destructive distillation, it affords carbonate of ammonia, and a peculiar compound, which sublimes in crystals, and which, according to Dr Henry, consists of a peculiar acid united to ammonia; a quantity of charcoal remains in the retort. Its ultimate constituents, according to Dr Prout, are

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[*] Phil. Trans. 1818.

1 proportional of nitrogen ——— 14
2 ——— carbon $6 \times 2 = 12$
1 ——— oxygen ——— 8
1 ——— hydrogen ——— 1
35*

Phosphate of lime.

2152. *Phosphate of Lime* may be precipitated from urine by the addition of ammonia; its relative quantity is liable to much fluctuation; sometimes it becomes so great as to be deposited as the urine cools, constituting what has been termed *white sand.*

— of ammonia, &c.

2153. The *Phosphates of Ammonia*, of *Soda*, and of *Magnesia*, and *common Salt*, constitute the principal crystallizable salts contained in the urine; the first of these is probably in great part produced during evaporation, for the saline mass obtained by inspissating urine is no longer acid; the carbonic having escaped, and the phosphoric being saturated by ammonia. The *microcosmic salt*, or *fusible salt of urine*, of the old chemists, is chiefly phosphate of ammonia with a little phosphate of soda, or perhaps a triple *ammonio-phosphate of soda.* (920).

Ammoniaco-magnesian phosphate.

2154. The *Ammoniaco-magnesian Phosphate* (1061) is a common, and almost constant ingredient in urine. It forms a part of the white sand voided in certain calculous affections, and is sometimes formed in a film upon the surface of the urine, having been held in solution by carbonic acid, and being deposited as that gas escapes.

Sulphuric acid.

2155. The existence of *Sulphuric acid*, probably combined with *soda*, and perhaps also with *potassa*, may be detected in urine by the addition of nitrate of baryta, which occasions a precipitate of sulphate of baryta.

As urine blackens silver, it has been said to contain *sulphur;* but this is not the case with recent urine, and when it becomes slightly putrid it evolves a little sulphuretted hydrogen.

Albuminous matter.

2156. The existence of *albuminous matter* in urine is sometimes easily demonstrated; at others, the secretion seems not to contain it. It has been said, by Mr Cruickshank, that the urine in some dropsical cases contains so much albumen as to be coagulable by heat,† but if that ever be the case, the secretion could hardly be called urine. It seems questionable whether the albumen of urine should not sometimes be regarded as derived from the mucous secretion of the bladder. Dr Prout, in his *Inquiry into the Nature and Treatment of Gravel*, &c. has described some cases of albuminous urine, and has adverted to its method of cure.

Urea.

2157. *Urea* is the principle which confers upon urine its chief peculiarities. It may be obtained by slowly evaporating urine to the consistency of sirup; on cooling it concretes into a saline mass, which by digestion in alcohol, furnishes urea. By carefully distilling off the alcohol, the urea remains in the form of a brown crystallized mass, which, by purification, furnishes colourless prismatic crystals.

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* The *urates* have principally been examined by Dr Henry, and an account of many of them is given in his *Thesis* above quoted.

† Phil. Mag. vol. ii.

Other processes have been given for obtaining urea, which are objectionable, on account of their complexity; indeed it is doubtful whether, by the action of heat and alcohol, as above described, it is not considerably altered.

Properties.

Urea is very soluble; water, at 60°, takes up about its own weight, and boiling water appears to dissolve it in any quantity, and without alteration: boiling alcohol takes up its own weight, and on cooling the urea separates in crystals. Sulphuric ether scarcely dissolves an appreciable portion. Nitric acid produces a crystalline precipitate in the aqueous solution of urea consisting of the two substances according to Dr Prout, in the following proportions:

Nitric acid	47,37
Urea	52,63
	100,00

A very similar compound may also be produced with oxalic acid.

The fixed alkalies decompose urea, and occasion the evolution of ammonia and some other products. It is to this substance that the copious production of volatile alkali, during the destructive distillation of urine, is referable; and the ammonia which is found in combination with the acids, in putrid urine, is derived from the same source.

Urea combines with most of the metallic oxides; with oxide of silver the compound is grey, and it decomposes with detonation when heated.

According to Dr Prout's analysis urea* consists of

Oxygen . . .	26,66	= 1	proportional	8
Nitrogen . .	46,66	= 1	„	14
Carbon . . .	19,99	= 1	„	6
Hydrogen . .	6,66	= 2	„	2
				30

In some diseased states of the urine there is a morbid excess of urea, which may be detected by putting a little of the urine into a watch-glass, and carefully adding an equal quantity of nitric acid, in such a manner that the acid shall subside to the lower part of the glass; if spontaneous crystallization take place it indicates excess of urea.†

Effect of diseases.

2158. Such are the properties of the principal ingredients in human urine, to which several others have been added by different chemists; but their existence is only occasional, and often doubtful.

2159. The urine suffers some very remarkable changes in certain diseases, which have been but superficially inquired into by chemists. In cases of injury of the spine, affecting the nerves that supply the kidneys; the urine is always turbid, and often alkaline; and there is a considerable tendency in these cases to form calculi.

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* Henry's *Elements*, vol. ii.

† Prout, on *Gravel*, &c. p. 10.

Diabetes.

In the disease called *diabetes*, the urine is not only secreted in excess, but often contains a substance of a sweet taste, having the properties of sugar, and its specific gravity is considerably above the healthy standard.*

2160. The urine of graminivorous animals differs considerably from that of the human subject. Carbonates, muriates, and phosphates, are the leading ingredients; it also contains urea, but not uric acid; potassa is usually the predominating alkali.

Sand.

2161. It frequently happens, from a variety of causes, that certain ingredients of human urine are secreted in excess, and deposited in a solid form, constituting *sand*, or *gravel* and *calculi*.

Sand is either *white* or *red;* the former consists of phosphate of lime, and ammoniaco-magnesian phosphate, either separate or mixed, and the latter is chiefly uric acid. The former deposition is prevented by the use of acids, and the latter by alkalies and the alkaline earths. The modes of exhibiting these remedies, and the effects which they produce, are described in a paper printed in the *Quarterly Journal of Science and Arts*, Vol. vi.

Calculi.

2162. Urinary calculi are, for the most part, composed of materials that exist at all times in the urine, though there are a few substances that only make their occasional appearance in them. The following are their component ingredients:

Components.

1. Uric acid.
2. Urate of ammonia.
3. Phosphate of lime.
4. Ammonio-magnesian phosphate.
5. Oxalate of lime.
6. Carbonate of lime.
7. Cystic oxide.

Uric acid calculus.

2163. The calculi composed of uric acid, of which the chemical properties have already been described (2149), are of a brown or fawn-colour; and, when cut through, appear of a more or less distinctly laminated texture. Their surface is generally smooth, or nearly so, being sometimes slightly tuberculated. Before the blow-pipe this calculus blackens, and gives out a peculiar ammoniacal odour, leaving a minute portion of white ash: it is soluble in solution of pure potassa, and heated with a little nitric acid, affords the fine pink compound, abovementioned (2150).

Phosphate of lime calculus.

2164. Phosphate of lime calculus is of a pale brown, or grey colour, smooth, and made up of regular and easily separable laminæ. It is easily soluble in muriatic acid and precipitated by pure ammonia, and does not fuse before the blow-pipe. *Calculi from the prostrate gland*, are always composed of phosphate of lime.

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* Henry on *Diabetic Urine. Medico-Chirurgical Trans.* Vol. ii. p. 118.

Triple calculus.

2165. The ammonio-magnesian, or triple calculus, is generally white, or pale grey, and the surface often presents minute crystals; its texture is generally compact, and often somewhat hard and translucent; heated violently by the blow-pipe, it exhales ammonia, and leaves phosphate of magnesia. It is more easily soluble than the preceding, and oxalate of ammonia forms no precipitate in its muriatic solution.

Fusible calculus.

2166. It frequently happens that calculi consist of a mixture of the two last-mentioned substances, in which case they melt before the blow-pipe, and are hence termed *fusible calculi.* They are white or nearly so, and softer than the separate substances, often resembling chalk in appearance. They are easily soluble in muriatic acid, and if oxalate of ammonia be added to their solution, the lime is precipitated in the state of oxalate.

Mulberry calculus.

2167. Oxalate of lime forms calculi, the exterior colour of which is generally dark brown, or reddish; they are commonly rough, or tuberculated upon the surface, and have hence been called *mulberry calculi.* Before the blow-pipe they blacken and swell, leaving a white infusible residue, which is easily recognised as quicklime (1953). Small oxalate of lime calculi are, however, sometimes perfectly smooth upon the surface, and much resemble a hempseed in appearance.

Urate of ammonia.

2168. Urate of ammonia is admitted by Prof. Brande among urinary calculi, upon the authority of Dr Prout.* Its surface is sometimes smooth, sometimes tuberculated; it is made up of concentric layers, and its fracture is fine earthy, resembling that of compact lime-stone; it is generally of a small size, and rather uncommon, though it often occurs mixed with uric acid. It usually decrepitates before the blow-pipe, is more soluble than the uric calculus, evolves ammonia when heated with solution of potassa, and is readily soluble in the alkaline carbonates, which pure uric acid is not.

2169. Dr Prout and Mr Smith† have described calculi composed almost entirely of carbonate of lime, but this species is exceedingly rare.

Cystic oxide.

2170. Cystic oxide is a peculiar animal substance; the calculi composed of it, which are rare, are in appearance most like those of the ammonio-magnesian phosphate. They are soft, and when burned by the blow-pipe, exhale a peculiar fetid odour. They are soluble in nitric, sulphuric, muriatic, phosphoric, and oxalic acids, and also in alkaline solutions.

2171. The substances which have been described, with the exception of cystic oxide, are sometimes intimately blended in calculi; sometimes they form alternating layers; and in a few cases four distinct layers have been observed, the nucleus being uric, upon which the oxalate, and phosphate of lime, and the triple phosphate, are distinctly and separately arranged.

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* Phil. Trans. 1808.

† Med. et Chir. Trans. xi. 14.

Xanthic oxide.

2172. Dr Marcet has described a calculus composed of a peculiar animal matter, which he calls *Xanthic Oxide*, from its property of giving a yellow colour when acted on by nitric acid: he has also announced the existence of calculus composed of *fibrine*.[*]

2173. These are the principal chemical facts belonging to the history of urinary calculi. In Dr Wollaston's and Prof. Brande's valuable papers upon this subject[†] much additional information will be found.[‡]

SECTION VII. *Cutis, or Skin, Membrane, &c.*

2174. THE skin of animals consists of an exterior albuminous covering, or *cuticle*, under which is a thin stratum of a peculiar substance, called by anatomists *rete mucosum*, and which lies immediately upon the *cutis*, or true skin, of which the principal component is *gelatine*.

Gelatine.

2175. The following are the chemical properties of pure gelatine. It is colourless, semi-transparent, and nearly tasteless. It is softened by long continued immersion in cold water: in hot water it readily dissolves, and forms a solution of a slightly milky appearance, which, if sufficiently concentrated, concretes on cooling into the tremulous mass usually called *jelly*, and which is easily soluble in cold water; when dried in a gentle heat it acquires its original appearance, and is as soluble as before. When dry, gelatine undergoes no change, but its solution soon becomes mouldy and putrescent. Submitted to the action of heat it affords the usual products of animal substances.[§]

It is readily soluble in diluted acids and alkaline solutions, and forms no soap with the latter. Its aqueous solution is not affected by solution of corrosive sublimate, and few of the metallic salts occasion any precipitate in it. Chlorine passed through its solution, occasions a white elastic matter to separate, which is not soluble in water, and which in some properties resembles albumen. It is insoluble in alcohol and ether.

Action of tannin.

Solution of tannin occasions a white precipitate in solution of gelatine; and hence, vegetable astringents such as galls or catechu, are generally employed as tests for its presence. But as tannin precipitates albumen, it cannot be relied on as an unequivocal test, unless we previously ascertain the non-existence of albumen by corrosive sublimate.[||]

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[*] Essay on Calculous Disorders, 2d edit. p. 103.

[†] Phil Trans. 1797 and 1810.

[‡] Dr Marcet and Dr Prout have published excellent dissertations on *Calculous Disorders*, containing all that is most important upon the subject.

[§] Hatchett. *Philos. Transact.* vol. xc.

[||] Bostock. Nicholson's *Journal*, xiv. and xxi.

Sulphate of platinum a test of gelatine.

Mr E. Davy recommends sulphate of platinum as a very delicate test of gelatine, with which it forms a brown insoluble compound, in solutions too weak to be affected by vegetable astringents.*

Action of sulphuric acid.

2176. The action of sulphuric acid upon gelatine has been investigated by M. Braconnot. Twelve parts of powdered glue and 24 of sulphuric acid, were left together for 24 hours; about 60 parts of water were then added, and the whole boiled for 5 hours, adding water at intervals; the solution was then saturated with chalk, filtered, and suffered to evaporate spontaneously. In a month crystals were deposited, which, being purified by solution and a second crystallization, much resembled sugar of milk, though they differ from that substance in affording a peculiar acid, called by M. Braconnot *Nitro-saccharine acid,* when acted upon by nitric acid.†

2177. The different kinds of gelatine differ considerably in viscidity. Mr Hatchett has remarked that the gelatine obtained from skins possesses a degree of viscidity inversely as their softness or flexibility; the most adhesive kinds of gelatine, too, are less easily soluble in water than those which are less tenacious. The principal varieties of gelatine in common use are,

Glue.

a. Glue, which is prepared from the clippings of hides, hoofs, &c., obtained at the tan-yard; these are first washed in lime-water, and afterwards boiled and skimmed; the whole is then strained through baskets, and gently evaporated to a due consistency; afterwards it is cooled in wooden moulds, cut into slices, and dried upon coarse net-work. Good glue is of a semi-transparent and deep brown colour, and free from clouds and spots. When used it should be broken into pieces, and steeped for about 24 hours in cold water, by which it softens and swells; the soaked pieces may then be melted over a gentle fire, or in a water-bath, and in that state applied to the wood by a stiff brush. Glue will not harden in a freezing temperature, the stiffening depending on the evaporation of its superfluous water.

Size.

b. Size is less adhesive than glue, and is obtained from parchment shavings, fish-skin, and several animal membranes. It is employed by bookbinders, paper-hangers, and painters in distemper, and is sometimes mixed with flour, gum, &c.

Isinglass.

c. Isinglass is prepared from certain parts of the entrails of several fish; the best is derived from the sturgeon, and is almost exclusively prepared in Russia. It should be free from taste and smell, and entirely soluble in warm water, which is seldom the case, in consequence of the presence of some albuminous parts. When the jelly of isinglass is concentrated by evaporation and carefully dried, it forms a very choice kind of glue.‡

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* Phil. Trans. 1820, p. 119.

† Ann. de Chimie et Phys. xiii.

‡ Aikin's *Dictionary*, Art. Gelatine.

mon temperatures. The table below shows their relative proportions in different fats and oils :*

These principles may be obtained by boiling hogs' lard in alcohol; the fluid, on cooling, deposits a crystalline matter, which is to be purified by a second solution and crystallization; it is then pure *stearine*, white, brittle, tasteless, and inodorous; it fuses at a little below 120°, and forms soap with alkalies.

When the alcohol which has deposited the whole of the stearine is distilled, an oily liquid remains, which is *elaine*. It is fluid at 58°; it generally is of a yellow colour, and is convertible into soap.

Margaritic acid.

2187. When soap composed of hogs'-lard and potassa, is put into water, a portion only is dissolved, the remainder consists of white scales, composed of the alkali united to a peculiar acid, called by Chevreul, from its pearly appearance, *margaritic acid*, and separable from the above combination by muriatic acid.

It is insoluble in water, tasteless, fusible at 134°, and crystallizes on cooling in brilliant white needles. It is soluble in alcohol. It unites with potassa in two proportions, the one compound containing 100 acid + 8,80 potassa; the other, 100 acid + 17,77 potassa. These compounds have been termed *margarates of potassa.*

Oleic acid.

2188. The portion of the hogs'-lard soap soluble in water, consists of another peculiar substance united to potassa, which Chevreul has called *oleic acid.* It may be obtained from its solution by tartaric acid, which causes it to separate in the form of an oily matter, that is to be again united to potassa, and separated as before. This substance solidifies at about 40°, and it forms compounds, called *oleates.* It appears probable that, by the action of alkalies, the stearine is converted into what Chevreul has termed margaric acid, and the elaine into oleic acid.†

2189. By mixing 1 volume of carbonic acid with 10 of carburetted hydrogen, and 30 of hydrogen, and passing the mixture through a red-hot porcelain tube, Berard is said to have produced a substance in small white crystals, having many of the properties of fat.‡

Spermaceti.

2190. *Spermaceti* or *Cetine* is a peculiar matter, which concretes from the oil of the *spermaceti whale.* It fuses at 112°, and at higher temperatures is volatile, but if repeatedly distilled it loses its solid form, and becomes a liquid oil. It is soluble in boiling alcohol, and abundantly so in ether. It forms a soap with potassa, which yields, on decomposition, a substance called by Chevreul, *cetic acid.*§

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*	Elaine.	Stearine.		Elaine.	Stearin
Butter, made in summer	60	40	Goose-fat	68	32
Ditto, winter	37	63	Ducks'-fat	72	28
Hogs'-lard	62	38	Turkey's-fat	74	26
Beef-marrow	24	76	Olive-oil	72	28
Mutton ditto	74	26	Almond-oil	76	24

† Annales de Chimie, xciv.

‡ Thomson's *Annals*, xii.

§ Annales de Chimie, xc

2191. In the *yolk* of *eggs* there is a considerable quantity of oily matter, which may be obtained by pressure after boiling; it is yellow and tasteless.

2192. *Ambergris*, which is a concretion from the intestines of the spermaceti whale, also contains a considerable portion of fatty matter, amounting in some specimens to 60 *per cent.* It is only found in the unhealthy animal.* Ambergris.

2193. The brain of animals, when boiled in alcohol, furnishes a peculiar fatty matter, which the solution deposits as it cools, in brilliant scales. It requires a higher temperature than that of boiling water for its fusion, and appears in many respects analogous to cholesterine. (2130.) The same substance is often seen in the alcohol employed to preserve anatomical preparations of the brain and nerves.

SECTION X. *Cerebral Substance.*

2194. ACCORDING to Vauquelin, the *cerebral substance* consists of

Water	80,00
White fatty matter	4,53
Red fatty matter	0,70
Albumen	7,00
Osmazome	1,12
Phosphorus	1,50
Acids, salts, and sulphur	5,15
	100

The *pulp of nerves* seems to be of a similar nature.†

SECTION XI. *Shell and Bone.*

2195. We are indebted to Mr Hatchett for two excellent dissertations on the chemical properties of these parts of animals, published in the *Philosophical Transactions* for 1799 and 1800.

He has divided *shells* into two classes; the texture of the first is compact, brittle, and resembling porcelain; their surface is smooth, and they are often beautifully variegated. When exposed to a red heat they crackle, and lose the colour of their enamelled surface, emitting scarcely any smoke or smell. They dissolve in dilute muriatic acid with copious effervescence, and form a transparent solution, in which neither pure ammonia nor acetate of lead produce any precipitate, but carbonate of ammonia throws down carbonate of lime. Hence these, which are

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* Home's *Lectures on Comparative anatomy*, Vol. I. p. 470.

† Thomson's *System*, Vol. iv. p. 482.

Porcellaneous shells. called *porcellaneous shells*, may be considered as composed of carbonate of lime, united to a very small portion of gelatine: most of the univalve shells, such as whelks, limpets, cowries, and many of the beautiful convoluted shells of tropical countries, belong to this class.

Mother-of-pearl shells. 2196. The second class, or *mother-of-pearl shells*, are tougher, glossy, and iridescent; they are mostly bivalves, and all the oyster and muscle species belong to it. When heated, they exhale smoke and the smell of burned horn; immersed in muriatic acid, they only partially dissolve, and leave a series of cartilaginous layers, and an outer epidermis. Each membrane appears to have a corresponding stratum of carbonate of lime, the solution indicating no trace of any phosphate. The animal part is in some cases, as in mother-of-pearl, tough and indurated, and when dried becomes exactly like horn; in other instances, as in the bone of cuttle fish, it appears in the form of delicate and tender membrane.

In both classes of shells, therefore, the hardening principle is carbonate of lime; in porcellaneous shells there is very little animal matter which is gelatine; and in mother-of-pearl shells, it is albumen, and in larger quantities.

Pearls. 2197. *Pearls* are exactly similar in composition to what is termed *mother-of-pearl*, in which Mr Hatchett found

Carbonate of lime	66
Albumen	24
	100

Scales of fish. 2198. In the *scales of fish*, and in the *crusts* of lobsters, crabs, prawns, and cray-fish, Mr Hatchett found the animal portion to consist of cartilage; the hardening part was a mixture of carbonate and phosphate of lime. From *lobster-shell* Merat-Gulliot obtained

Carbonate of lime	60
Phosphate of lime	14
Cartilage	26
	100

Vauquelin obtained from 100 parts of *hen's egg shell*

Carbonate of lime	89,6
Phosphate of lime	5,7
Animal matter	4,7
	100

Zoophytes. 2199. *Zoophytes*, according to Mr Hatchett's researches, may be divided into four classes; the first resemble porcellaneous shells, and consist entirely of carbonate of lime, with a very minute quantity of gelatinous matter; of this the common white coral (*madrepora virginea*) is an example. The second consists of carbonate of lime, and a cartilaginous substance, and are therefore analogous to mother-of-pearl shell; to this class belong the *madrepora ramea*, and *madrepora fascicularis.* The third class is composed of a cartilaginous matter, with carbonate and phosphate of lime; to this belongs the red coral (*gorgonia nobilis*). The fourth class contains sponges, composed almost entirely of albuminous matter.*

Bone and Ivory.

2200 *Bone*, and *Ivory*, like the preceding substances, is essentially composed of soft and hard parts. When ground bone is digested in warm water, a portion of fat is first separated, and by long-continued ebullition, a solution which gelatinizes on cooling is obtained. If fresh bone be immersed in diluted muriatic acid, the fat, gelatine, and hardening matter are dissolved, and a kind of skeleton of the bone remains in the form of a cartilaginous substance, which when dried exactly resembles horn. It appears, therefore, that the soft parts of bone are, *fat*, *gelatine*, and *albumen.*

The earthy salts, which constitute the hardening principle of bone, are phosphate and carbonate of lime, with a minute quantity of sulphate of lime, and traces of phosphate of magnesia. Fourcroy and Vauquelin obtained from ox-bones,

Animal matter	51
Phosphate of lime	37,7
Carbonate of lime	10
Phosphate of magnesia	1,3
	100

Enamel of teeth.

2201. The *enamel of teeth* is perfectly destitute of cartilage, and consists chiefly of phosphate of lime and a portion of gelatine. Mr Pepys found its component parts

Phosphate of lime	78
Carbonate of lime	6
Gelatine	16
	100

The same chemist has given the following as the composition of the teeth (Fox, *On the Teeth*:)

	Roots of the teeth.	Teeth of Adults.	First Teeth. of Children.
Phosphate of lime	58	64	62
Carbonate of lime	4	6	6
Cartilage	28	20	20
Loss	10	10	12
	100	100	100

Destructive distillation of bones.

2202. When bones are submitted to destructive distillation, the gelatine and albumen which they contain are abundantly productive of ammonia; water, and carbonic acid are also formed and a portion of highly fetid empyreumatic oil. There remains in the vessel a quantity of charcoal mixed with the earthy substances, which is, in that state, called *ivory black*. It is employed as the basis of some black paints and varnishes.

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* Phil. Trans. 1800.

Section XII. *Of Animal Functions.*

2203. Chemistry has hitherto done little towards elucidating the functions of animals, and it is scarcely possible to describe the little that has been done, without such frequent reference to anatomical and physiological inquiries as would be irrelevant to the present work; we shall, therefore, only enumerate the principal chemical phænomena that have been experimentally illustrated, in relation to this subject.

Digestion. 2204. *Digestion* is a process by which the food of animals is converted into chyle, and which in conjunction with *respiration*, tends to the production of blood. The mechanism by which it is carried on differs considerably in the different classes of animals; the present remarks will relate chiefly to man, and to the carnivorous tribe.

Chyme. The food, duly masticated in the mouth, and blended with a considerable portion of saliva, is propelled into the stomach, where it soon undergoes a remarkable change, and, in the course of a few hours, is converted into an apparently homogeneous pulpy mass, which has been termed *chyme*, and which has little or no resemblance to the original food. This very curious change is only referable to the operation of a secretion peculiar to certain glands of the stomach; it has been termed *gastric juice*, and all that is known respecting it is, that it has very energetic solvent powers, in regard to the greater number of animal and vegetable bodies; the remarkable property of living substances to resist its action is curiously illustrated by the circumstance that the stomach itself, after death, is occasionally eaten into holes by its action; it instantly coagulates all albuminous substances, and afterwards softens and dissolves the coagulum. There are some substances that remarkably resist its action, such as the husk of grain, and of many seeds, which, if not previously broken by mastication, pass through the stomach and bowels nearly unaltered. It is hardly worth while to detail the experiments that have been undertaken on the gastric juice, since they are much at variance, and it is impossible to say whether the secretion has ever been examined in a state even approaching to purity. It has been described as a glairy fluid, of a saline taste; sometimes it is said to be acid, and sometimes bitter; but no light whatever has been thrown by any of these researches upon the cause of its singular solvent energies.

It has sometimes been matter of surprise, that although animals drink copiously with their food, the consistency of the chyme is not affected by it, and by the time that it reaches the right, or pyloric extremity of the stomach, the liquid has disappeared. Sir Everard Home's curious physiological researches have shown that liquids are copiously and rapidly removed by absorbents belonging principally to the left, or cardiac por-

Absorption from the stomach.

tion of the stomach, and that during digestion there is an imperfect division of the stomach into two cavities, by the contraction of the bands of muscular fibres about its centre. He has also shown that these liquids, very soon reach the kidneys, and pass off by urine; and was led to believe that the spleen was the channel of communication; an opinion, however, which his subsequent researches tended to disprove.[*]

The chyme passes from the stomach into the small intestines, where it soon changes considerably in appearance; it becomes blended with bile, and is separated into two portions, one of which is white as milk, and is termed *chyle*; the other passes on to the large intestines, and is ultimately voided as excrementitious. The chyle is absorbed by the *lacteals*, which terminate in the common trunk, called the *thoracic duct*; it is there mixed with variable proportions of lymph, and poured into the venous system.

Chyle.

The *excrements of animals* have been examined by Berzelius,[†] by Vauquelin,[‡] and by Thaer and Einhoff. An abstract of these experiments has been published by Dr Thomson, in the 4th volume of his *System of Chemistry*.

2205. *Chyle* has been examined by several chemists, and their results are not widely different. During some physiological researches Prof. Brande and Mr Brodie had an opportunity of collecting it in considerable quantities in several carnivorous and graminivorous animals, and an account of experiments upon it was presented to the Royal Society.[§]

Characters.

Chyle is an opaque white fluid, having a sweetish saline taste; its specific gravity is inferior to that of the blood. It exhibits slight traces of alkaline matter when tested by infusion of violets; soon after removal from the thoracic duct, it gelatinizes spontaneously, and afterwards gradually separates into a firm yellowish white coagulum, and a transparent colourless serum; so that, like the blood, it enjoys the property of spontaneous coagulation.

The *coagulum of chyle* possesses properties closely resembling those of the caseous portion of milk, and may hence be considered as a variety of albumen; the *serum of the chyle*, when heated, deposits a few flakes of albumen, and by evaporation to dryness affords a small proportion of a substance analogous to sugar of milk. Small portions of phosphate of lime, carbonate of soda, and common salt, may also be detected in the chyle. In these experiments Prof. Brande found no distinctive difference in the chyle of graminivorous and carnivorous animals, he examined it from the horse, the ass, the dog, and the cat; Dr Marcet thinks that the former is less abundant in albumen than the latter.[‖]—THOMSON's *Annals*, Vol. vii.

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[*] Lectures on Comparative Anatomy, p. 221.

[†] Gehlen's *Journal*, vi.

[‡] Annales de Chimie, xxix.

[§] Brande in *Phil. Trans.* 1812, p. 91.

[‖] It is a curious question, whence the nitrogen, which constitutes an abundant ultimate principle of the chyle of herbivorous animals is derived; we find it in very small proportion only in their ordinary food, and yet I could discern no difference in the composition of the albuminous portion of their chyle, and that of animals fed exclusively on meat. (Brande.)

Bile. 2206. There can be little doubt that the bile performs an important part in the change which the chyme suffers in the small intestines; it has been conjectured that its aqueous, and perhaps its alkaline parts, are employed as components of chyle, while the albumino-resinous matter combines with the excrementitious portion, and tends to stimulate the intestinal canal towards promoting its propulsion. Whether the bile is absolutely necessary to the formation of chyle, is a question that has not been satisfactorily answered; but its importance is demonstrated by the emaciation that attends its deficiency, and by the disordered state of bowels that accompanies its imperfect secretion. Sir Everard Home, in his *Lecture on the Functions of the Lower Intestines*,* has offered some curious facts connected with this subject, to which the physiological reader is referred. He is of opinion that, in the large intestines, a portion of the food unfit for chylification is, by a process not widely different from that above described, (2108) converted into fat, which is afterwards absorbed and conveyed to different parts of the body.

2207. In chyle we cannot fail to observe a close approximation to blood; it is deficient only in colouring matter, and the albumen which it contains differs a little from that existing in the blood itself; it appears therefore, that the albumen is perfected, and the colouring matter formed, in the process of circulation; the saccharine principle of the chyle is also no longer perceptible.

Respiration. 2208. *Respiration* is the process of receiving a quantity of air into the lungs, whence, after having been retained a short time, it is again expelled in the action of expiration; and, if now examined, a portion of its oxygen is found converted into carbonic acid, and it is more or less loaded with aqueous vapour.

Number of respirations. Obvious circumstances render it very difficult to ascertain the quantity of air taken into the lungs at each natural inspiration, as well as the number of respirations made in a given time; the former is perhaps about 15 or 16 cubic inches, and the latter about 20 in a minute.

Changes of the air respired. It has been by some supposed that the air suffers an absolute diminution of bulk, but the experiments that have been adduced to prove this, can scarcely be regarded as satisfactory; it seems, on the contrary, most probable that the volume of air expired is exactly equal to that inspired, and consequently the only chemical change that is evident is the saturation of a portion of of its oxygen with carbon. The quantity of carbonic acid emitted at each expiration, varies at different periods of the day, and probably also in different individuals; it appears at its maximum during digestion, and at its minimum in the morning when the stomach is empty, and when no chyle is flowing into the blood. Dr Prout has shown that fermented liquors and vegetable diet diminish the proportion of carbonic acid, and that the same thing happens when the system is affected by mercury.*

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* Lectures, p. 468.

Quantity of carbonic acid.

The air expired may be regarded, as containing, on an average, 3,5 per cent of carbonic acid, though Messrs Allen and Pepys, in their valuable *Essay on Respiration*,† have estimated it at about twice that quantity; it amounted, in their experiments, to 27,5 cubic inches per minute, a quantity probably above the truth, when we reflect upon the comparative proportion of carbon existing in our food, and the other means of escape which it has from the body.

The aqueous vapour contained in the expired air is secreted by the exhalents distributed over the surface of the air-vessels of the lungs; attempts have been made to estimate its quantity, but without success; it is probably liable to variation, and can scarcely be considered as a product of respiration.

The change of colour in the blood is evidently owing to the action of the air, which takes place through the thin coats of the circulating vessels, and the end thus attained is the removal of the carbon from the venous blood, by which the colouring matter was obscured: the carbon to be thus readily soluble in oxygen must be in some peculiar state; a portion of it is also removed by the absorbents, and transferred to the glands situate at the root of the lungs between the subdivisions of the bronchiæ, which often contain a large portion of black matter. This has sometimes been referred to soot inhaled with the air, but many circumstances render it more probable that it is a carbonaceous deposit from the blood. The only chemical difference, then, which can be detected between arterial and venous blood, is the existence of a certain excess of carbon in the latter, which it gives off to oxygen, forming carbonic acid; the blood is thus fitted for the renovation of parts, for the formation of secretions, and for the sustenance of life by its action on the cerebral system; for although the heart does not directly refuse to circulate venous blood, paralysis and torpor ensue when blood, not aërated, passes into the vessels of the brain.

Perspiration.

2209. It has been shown that the blood suffers very important changes in the kidneys and liver; the function of *perspiration* also must be considered as connected with an alteration of the circulating fluid, for moisture, carbonic acid, and minute quantities of phosphoric acid, and saline matter, among which is common salt, are evacuated by the cutaneous vessels.

Unequal quantity of oxygen necessary to different animals.

2210. Different animals require very different quantities of oxygen for the purpose of respiration. Man, and warm-blooded animals, consume the largest quantity; the amphibious tribes not only require less, but can breathe in an atmosphere which will not support the life of the former; and many insects take such small quantity, as sometimes to have been supposed capable of living without air, which is not the case. In the production of carbonic acid all animals agree, and consequently the nature of the deterioration suffered by the air is similar throughout the animal creation.

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* Thomson's *System*, iv. 621.

† Phil. Trans. 1808.

Fishes breathe the air which is dissolved in water; they therefore soon deprive it of its oxygen, the place of which is supplied by carbonic acid; this is in many instances decomposed by aquatic vegetables, which restore oxygen, and absorb the carbon; hence the advantage of cultivating growing vegetables in artificial fish-ponds. It has been ascertained by Biot, and verified by others, that the air-bladders of fish that live in very deep water are filled with a mixture of oxygen and nitrogen, in which the former greatly preponderates; but in fish that are taken near the surface, the nitrogen is most abundant. In the *trygla lyra*, always caught in very deep water, the air-bladder contained 87 per cent. of oxygen: in the carp and roach, according to Fourcroy and Priestley, the air-bladder contains little else than nitrogen.*

Animal heat.

2211. The production of *animal heat* is perhaps the most recondite of all the functions; the power appears to belong to all animals, though to some in a very inferior degree. The higher orders of animals always maintain a temperature of about 100°; it varies a little in different parts of the body, the extremities and surface being a degree or two colder than the interior vital organs. This temperature is probably very little affected by external circumstances, a hot or cold atmosphere producing no corresponding change in the heat of the circulating blood.

When the chemical changes that take place during respiration had been inquired into, and when it was found that the capacity of carbonic acid for heat was less than that of oxygen, it was supposed that the conversion of oxygen into carbonic acid was the cause of the rise of temperature: and as the heat of the lungs does not exceed that of the other parts, it was asserted that the air was absorbed by the blood, and that the production of carbonic acid, and consequent evolution of heat took place gradually during the circulation. To these opinions many strong objections have from time to time been urged by different physiologists, but their complete subversion followed the researches of Mr Brodie,† who found that the heart was capable of retaining its functions for some hours, and of carrying on circulation in a decapitated animal, and consequently independent of the influence of the brain, when respiration was artificially carried on. Under these circumstances it was observed, that although the change of blood from the venous to the arterial state was perfect, no heat was generated, and that the animal cooled regularly and gradually down to the atmospheric standard. In more

Mr Brodie's experiments.

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* Biot, *Memoires d' Arcueil*, i. and ii.

† Phil. Trans. 1812.

than one instance Prof. Brande examined, at his request, the expired air, and found that it contained as much carbonic acid as was produced by the healthy animal; so that here circulation went on, there was the change of oxygen into carbonic acid, and the alteration of colour in the blood, and yet no heat whatever appeared to be generated.

In these cases a period was also put to the secretory functions; and it has been observed by several other physiologists, that if the nerves that supply any of the glands are injured or divided, there is a corresponding change or suspension of their secretion. Electricity has sometimes been supposed to have some connexion with the nervous influence, and the fact of some of the secretions being alkaline, while others are acid (corresponding to negative and positive influence), has been adduced in favour of the supposition,* but experiment has gone little way to sanction such a notion, and although it has been proved that the nervous influence contributes to the generation of heat in animals, that it presides over the phænomena of secretion, as well as of voluntary motion, the actual cause of this influence, or energy, remains among those mysteries of nature which, doubtless, for the wisest purposes, are hidden to the human understanding.

ADDENDA.

Liquefaction of Gases.—The following account of Mr Farraday's experiments on the condensation of several of the gases, is taken from his very valuable paper in the Philosophical Transactions for 1822.

Sulphurous acid.

Sulphurous Acid. (515). Mercury and concentrated sulphuric acid were sealed up in a bent tube, and being brought to one end, heat was carefully applied, whilst the other end was preserved cool by wet bibulous paper. Sulphurous acid gas was produced where the heat acted and was condensed by the sulphuric acid above; but when the latter had become saturated, the sulphurous acid passed to the cold end of the tube, and was condensed into a liquid. When the whole tube was cold, if the sulphurous acid was returned on to the mixture of sulphuric acid and sulphate of mercury, a portion was reabsorbed, but the rest remained on it without mixing.

Liquid sulphurous acid is very limpid and colourless, and highly fluid. Its refractive power, obtained by comparing it in water and other media, with water contained in a similar tube, appeared to be nearly equal to that of water. It does not solidify or become adhesive at a temperature of 0° F. When a tube containing it was opened, the contents did not rush out as with explosion, but a portion of the liquid evaporated rapidly, cooling another portion so much as to leave it in the fluid state at common barometric pressure. It was however rapidly dissipated, not producing visible fumes, but producing the odour of pure sulphurous acid, and leaving the tube quite dry. A portion of the vapour of the fluid received over a mercurial bath, and examined, proved to be sulphurous acid gas. A piece of ice dropped into the fluid instantly made it boil, from the heat communicated by it.

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* In the *Philosophical Transactions* for 1809, p. 385, Sir Everard Home has given an account of these views, in a paper entitled *Hints on the Subject of Animal Secretions.*

To prove in an unexceptionable manner that the fluid was pure sulphurous acid, some sulphurous acid gas was carefully prepared over mercury, and a long tube perfectly dry, and closed at one end, being exhausted, was filled with it; more sulphurous acid was then thrown in by a condensing syringe, till there were three or four atmospheres; the tube remained perfectly clear and dry, but on cooling one end to 0°, the fluid sulphurous acid condensed, and in all its characters was like that prepared by the former process.

Sulphurous acid vapour exerts a pressure of about two atmospheres at 45° F. Its specific gravity was nearly 1,42.

Sulphuretted hydrogen.

Sulphuretted Hydrogen. (554). A tube being bent, and sealed at the shorter end, strong muriatic acid was poured in through a small funnel, so as nearly to fill the short leg without soiling the long one. A piece of platinum foil was then crumpled up and pushed in, and upon that were put fragments of sulphuret of iron, until the tube was nearly full. In this way action was prevented until the tube was sealed. If it once commences, it is almost impossible to close the tube in a manner sufficiently strong, because of the pressing out of the gas. When closed, the muriatic acid was made to run on to the sulphuret of iron, and then left for a day or two. At the end of that time, much protomuriate of iron had formed, and on placing the clean end of the tube in a mixture of ice and salt, warming the other end if necessary, by a little water, sulphuretted hydrogen in the liquid state distilled over.

The liquid sulphuretted hydrogen was colourless, limpid, and excessively fluid. It did not mix with the rest of the fluid in the tube, which was no doubt saturated, but remained standing on it. When a tube containing it was opened, the liquid immediately rushed into vapour; and this being done under water, and the vapour collected and examined, it proved to be sulphuretted hydrogen gas. As the temperature of a tube containing some of it rose from 0° to 45°, part of the fluid arose in vapour and its bulk diminished; but there was no other change: it did not seem more adhesive at 0° than at 45°. Its refractive power appeared to be rather greater than that of water: it decidedly surpassed that of sulphurous acid. The pressure of its vapour was nearly equal to seventeen atmospheres at the temperature of 50°.

The specific gravity of sulphuretted hydrogen appeared to be 0,9.

Carbonic acid.

Carbonic Acid. (643). The materials used in the production of carbonic acid, were carbonate of ammonia and concentrated sulphuric acid; the manipulation was like that described for sulphuretted hydrogen. Much stronger tubes are however required for carbonic acid than for any of the former substances, and there is none which has produced so many or more powerful explosions. Tubes which have held fluid carbonic acid well for two or three weeks together, have upon some increase in warmth of the weather, spontaneously exploded with great violence; and the precaution of glass masks, goggles, &c. which are at all times necessary in pursuing these experiments, are particularly so with carbonic acid.

Carbonic acid is a limpid colourless body, extremely fluid, and floating upon the other contents of the tube. It distils readily and rapidly at the difference of temperature between 32° and 0°. Its refractive power is much less than that of water. No diminution of temperature to which I have been able to submit it, has altered its appearance. In endeavouring to open the tubes at one end, they have uniformly burst into fragments with powerful explosions.

Its vapour exerted a pressure of thirty-six atmospheres, at a temperature of 32°.

Euchlorine.

Euchlorine. (285). Fluid euchlorine was obtained by inclosing chlorate of potassa and sulphuric acid in a tube, and leaving them to act upon each other for twenty-four hours. In that time there had been much action, the mixture was of a dark reddish brown, and the atmosphere of a bright yellow colour. The mixture was then heated up to 100°, and the unoccupied end of the tube cooled to 0°: by degrees the mixture lost its dark colour, and a very fluid ethereal looking substance condensed. It was not miscible with a small portion of the sulphuric acid which lay beneath it; but when returned on to the mass of salt and acid, it was gradually absorbed, rendering the mixture of a much deeper colour even than itself.

Euchlorine thus obtained is a very fluid transparent substance, of a deep yellow colour. A tube containing a portion of it in the clean end, was opened at the opposite extremity; there was a rush of euchlorine vapour, but the salt plugged up the aperture; whilst clearing this away, the whole tube burst with a violent explosion, except the small end in a cloth in my hand, where the euchlorine previously lay, but the fluid had all disappeared.

Nitrous oxide.

Nitrous Oxide. (409). Some nitrate of ammonia, previously made as dry as could be by partial decomposition by heat in the air, was sealed up in a bent tube, and then heated in one end, the other being preserved cool. By repeating the distillation once or twice in this way, it was found on after-examination, that very little of the salt remained undecomposed. The process requires care. I have had many explosions occur with very strong tubes, and at considerable risk.

When the tube is cooled, it is found to contain two fluids, and a very compressed atmosphere. The heavier fluid, on examination, proved to be water, with a little acid and nitrous oxide in solution; the other was nitrous oxide.

It appears in a very liquid, limpid, colourless state; and so volatile that the warmth of the hand generally makes it disappear in vapour. The application of ice and salt condenses abundance of it into the liquid state again. It boils readily by the difference of temperature between 50° and 0°. It does not appear to have any tendency to solidify at—10°. Its refractive power is very much less than that of water, and less than any fluid that has been yet obtained in these experiments, or than any known fluid. A tube being opened in the air, the nitrous oxide immediately burst into vapour.

The pressure of its vapour is equal to above fifty atmospheres at 45°.

Cyanogen.

Cyanogen. (712). Some pure cyanuret of mercury was heated until perfectly dry. A portion was then inclosed in a green glass tube, in the same manner as in former instances, and being collected to one end, was decomposed by heat, whilst the other end was cooled. The cyanogen soon appeared as a liquid: it was limpid, colourless and very fluid: not altering its state at the temperature of 0°. Its refractive power is rather less, perhaps, than that of water. A tube containing it being opened in the air, the expansion within did not appear to be very great; and the liquid passed with comparative slowness into the state of vapour, producing great cold. The vapour, being collected over mercury, proved to be pure cyanogen.

A tube was sealed up with cyanuret of mercury at one end, and a drop of water at the other; the fluid cyanogen was then produced in contact with water. It did not mix, at least in any considerable quantity, with that fluid, but floated on it, being lighter, though apparently not so much so as ether would be, in the course of some days, action had taken place, the water had become black, and changes, probably such as are known to take place in an aqueous solution of cyanogen, occurred. The pressure of the vapour of cyanogen appeared to be 3,6 or 3,7 atmospheres at 45° Fahr. Its specific gravity was nearly 0,9.

Ammonia.

Ammonia. (457). When dry chloride of silver is put into ammoniacal gas, as dry as it can be made, it absorbs a large quantity of it: 100 grains condensing above 130 cubical inches of the gas: but the compound thus formed is decomposed by a temperature of 100° F. or upwards. A portion of this compound was sealed up in a bent tube, and heated in one leg, whilst the other was cooled by ice or water. The compound thus heated under pressure, fused at a comparatively low temperature, and boiled up, giving off ammoniacal gas, which condensed at the opposite end into a liquid.

Liquid ammonia thus obtained was colourless, transparent, and very fluid. Its refractive power surpassed that of any other of the fluids described, and that also of water itself. When the chloride of silver is allowed to cool, the ammonia immediately returns to it, combining with it, and producing the original compound. During this action a curious combination of effects takes place; as the chloride absorbs the ammonia, heat is produced, the temperature rising up nearly to 100°; whilst a few inches off, at the opposite end of the tube, considerable cold is produced by the evaporation of the fluid. When the whole is retained at the temperature of 60°, the ammonia boils till it is dissipated and re-combined. The pressure of the vapour of ammonia is equal to about 6,5 atmospheres at 50°. Its specific gravity was 0,76.

Muriatic acid.

Muriatic Acid. (366). When made from pure muriate of ammonia and sulphuric acid liquid muriatic acid is obtained colourless, as Sir Humphry Davy had anticipated. Its refractive power is greater than that of nitrous oxide, but less than that of water; it is nearly equal to that of carbonic acid. The pressure of its vapour at the temperature of 50°, is equal to about 40 atmospheres.

Chlorine.

Chlorine. (270). The refractive power of fluid chlorine is rather less than that of water.—The pressure of its vapour at 60° is nearly equal to 4 atmospheres.

Mr Brunel having been engaged during three years in endeavouring to apply the liquids resulting from the condensation of the gases, as mechanical agents has succeeded in producing quantities of liquid carbonic acid amounting to a pint and a half; and has been able so to arrange his apparatus as to confine the substance even at high temperatures by tubes of brass not above the $\frac{1}{30}$ of an inch in thickness.—*Quart. Jour.* No. xli.

New orange gas.

New Orange Gas. A German chemist M. Unverdorben, has discovered that after mixing together fluor-spar and chromate of lead, and distilling them in a leaden retort with sulphuric acid, a gas resulted which could not be collected, as it destroyed the glass. This gas gave a very thick yellow or red smoke, it was readily absorbed by water, which was then found to contain a mixture of chromic and fluoric acids. On coming in contact with the air, it deposited small red crystals, which were those of chromic acid. Prof. Berzelius collected the gas in glass flasks covered with melted resin, and filled with mercury. It gradually attacks the resin, deposits chromic acid in its mass, and penetrates even to the glass, which it decomposes without change of volume, the chrome being replaced by silicium. Ammoniacal gas burns in it with explosion; water dissolves it and yields an orange coloured fluid, which, evaporated to dryness in a platinum dish, leaves as a residue pure chromic acid; the fluoric acid volatilizes entirely. This method is at present the only one which gives chromic acid perfectly pure.

If the gas is received in a platinum vessel of some depth, whose sides have been slightly wetted, and into the bottom of which the gas has been made to descend, the water begins to absorb the gas, but, by and by, crystals of a fine red colour are seen to form round the opening of the metallic tube, which conveys the gas, and in a short time, the vessel is filled with a red snow, consisting of crystals of chromic acid. The fluoric acid dissipates itself in vapour, and absorbs the water. The crystals, when heated to redness in a platinum dish, begin at first to melt and afterwards by a slight explosion, accompanied with a flash of light, they decompose themselves into oxygen gas and the green protoxide of chromium.

A gas similar to this is obtained by distilling chromate of lead with chloride of sodium, which contains chrome combined with chlorine, in such proportions, that the water, by its decomposition, gives rise to the formation of the hydrochloric and chromic acids. This gas is red and may be collected over mercury.—*Edin. Jour. of Science*, iv. 129.

Naphthaline. *Naphthaline*, is a peculiar crystallizable substance, which is deposited from the naphtha distilled from coal tar, and consists of hydrogen and carbon, containing no oxygen, as Mr Brande ascertained (*Phil. Trans.* 1822, p. 473). It is soluble in alcohol and ether, and in the fixed and volatile oils. It has a pungent aromatic odour, melts at 180°, assuming a crystallized appearance as it cools, and boils at about the temperature of 400°. By repeated solution in alcohol and crystallization, it may be obtained of a fine white colour and pearly lustre.

Mr Faraday has discovered that during the mutual action of sulphuric acid and naphthaline, a compound of the acid with hydro-carbon is formed, differing from all known substances, and which, possessing acid properties and combining with salifiable bases to produce a peculiar class of salts, has been distinguished as the *Sulpho-naphthalic acid*. This acid is best obtained by introducing about two parts of naphthaline and one part of concentrated sulphuric acid into a flask, the temperature being raised until the naphthaline melts; the flask should be agitated: combination takes place and after repose and cooling in tubes, two substances are found, both in the solid state. The lighter is naphthaline, containing a little of the peculiar acid in union with it; it is crystalline and hard, like common naphthaline, but of a red colour; when melted and agitated with water, the acid is washed out, and the naphthaline separates. The lower and heavier substance is also crystalline but softer than the upper, and consists principally of the hydrated peculiar

Sulpho-naphthalic acid.

acid, containing some uncombined naphthaline, it is distinguished as the *impure solid acid.*

To obtain the pure acid, carbonate of baryta was rubbed in a mortar with the diluted impure acid which it neutralized forming salts of baryta. The impure acid containing free sulphuric acid, insoluble sulphate of baryta was formed from which a soluble salt was easily separated. The baryta was separated from the neutral and pure solution by the careful addition of sulphuric acid, the liquor after filtration was found to be a pure aqueous solution of the new acid. It had a bitter acid taste, changed the vegetable colours, and combined with and neutralized all bases. By evaporation at a low temperature, it yielded the acid in a white solid crystalline form, unchangeable in close vessels, but deliquescing in the air. Heated to 212° it melted and crystallized on cooling; at higher temperatures it gave off water, then changed colour, charred, and ultimately produced naphthaline, sulphurous acid, and charcoal.

The salts which it forms with bases are all soluble in water and in alcohol. By Mr Faraday's analysis of the salt formed with baryta, it was found to consist of

		Or nearly	
Baryta	78,00	1	proportional
Sulphuric acid	85,35	2	proportionals
Carbon	118,54	20	———
Hydrogen	8,13	8	———

Abstracting the baryta it leaves the elements of the acid.—*Quart. Jour.* No. 41, p. 182.

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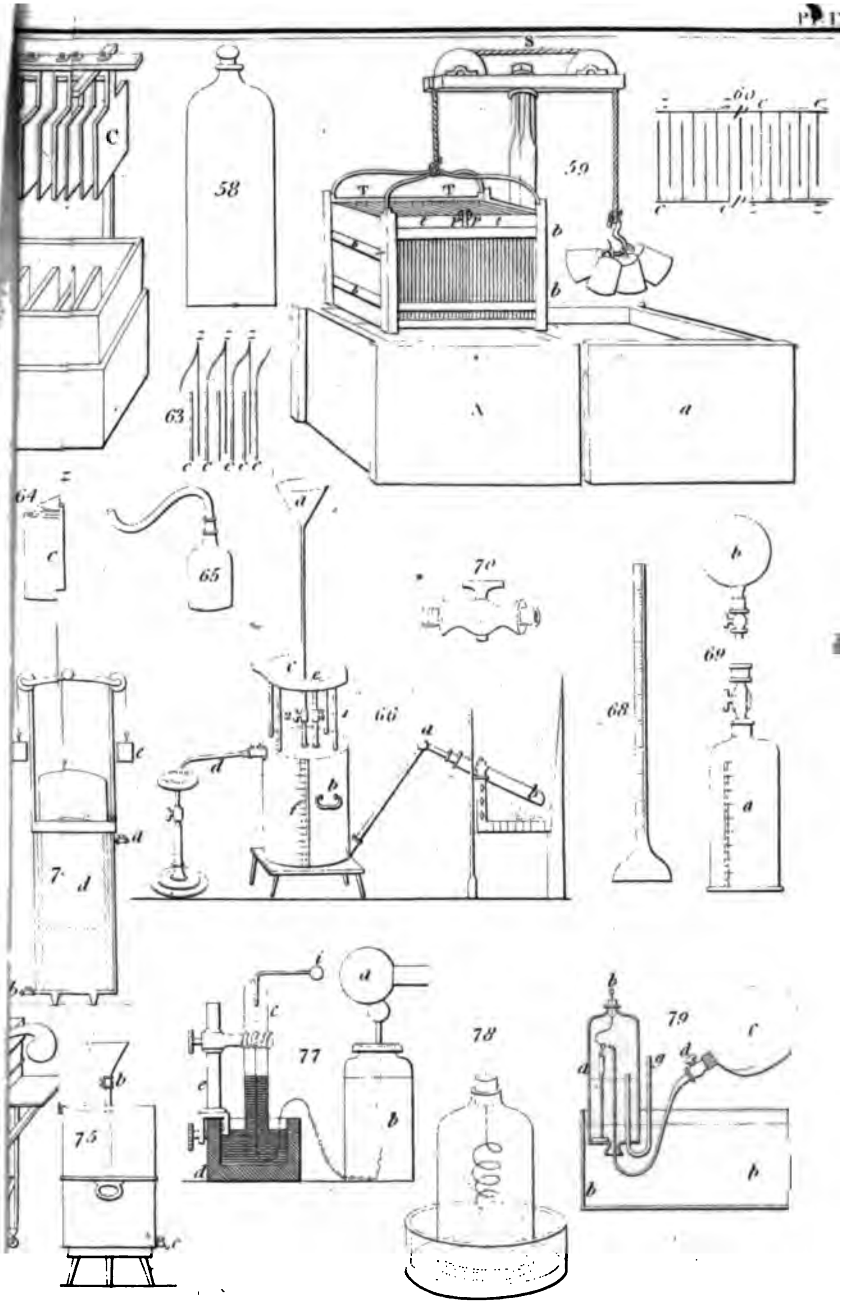
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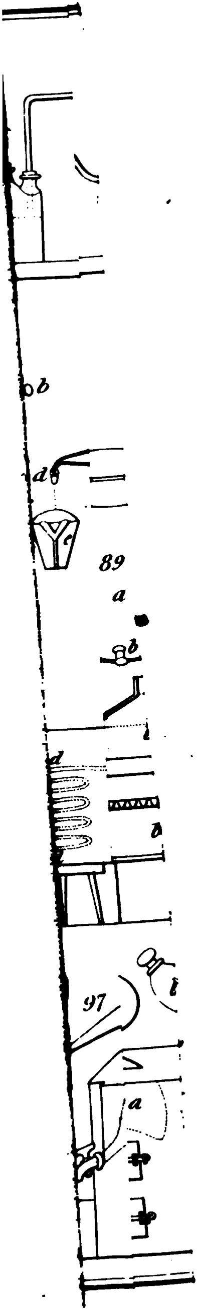

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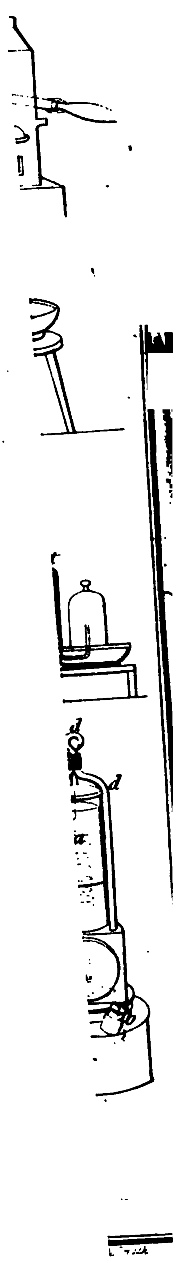

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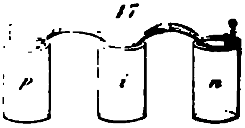

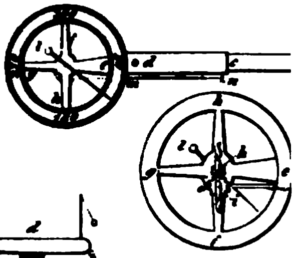

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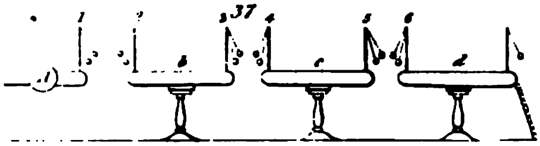

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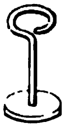

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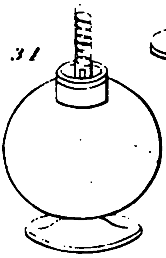

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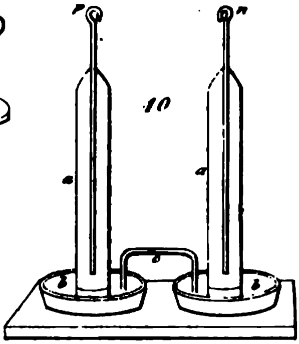

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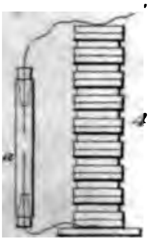

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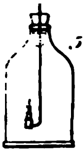

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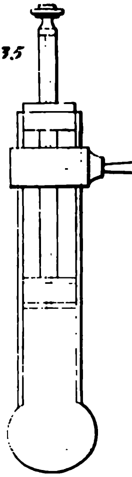

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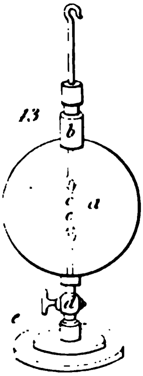

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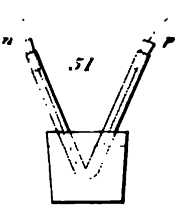

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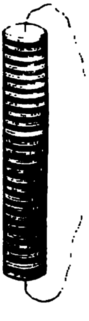

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